PSD PERMIT APPLICATION
FOR NEW SOURCES TO BE
ADDED TO THE
KUPARUK, ALASKA OIL FIELD

Submitted by:
Arco Alaska, Inc.

Submitted to:
U.S. Environmental Protection Agency Region X
and the
State of Alaska
Department of Environmental Conservation

Prepared by:
Radian Corporation

30 April 1981

DCN 81-121-241-02

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1.0 EXECUTIVE SUMMARY

Purpose

The purpose of this document is to support an application for a permit to construct additional facilities at the Kuparuk, Alaska Oil Field in accordance with the requirements of the United States Environmental Protection Agency's (USEPA) Prevention of Significant Deterioration (PSD) regulations which were promulgated August 7, 1980. This document is presented by ARCO Alaska, Inc., a subsidiary of Atlantic Richfield Company (ARCO).

Project Description

Additional facilities will be constructed to continue the development of the Kuparuk Oil Field. These consist of additional drill sites, expansion of the existing Central Production Facility (CPF), three other production facilities, water injection facilities, additional power production capacity, and a crude oil topping unit.

Project Schedule

Commitment of funds for the project may begin as early as mid-1981 with operations starting between early 1983 and late 1988.

Air Pollution Emission Sources

Atmospheric emissions from the proposed additional facilities will be produced by heaters at the drill sites, turbines and heaters at the production facilities, and the crude oil topping unit flare at the Central Production Facility. Total potential emissions from the proposed sources are shown below:

Pollutant	Potential Emissions (tons/year)
NO_x	15,402
PM	373
CO	3,006
SO_2	99
VOC	64

Regulatory Applicability

According to the PSD regulations promulgated on August 7, 1980, the proposed additional facilities constitute a major stationary source and are therefore subject to PSD review. The proposed facilities are also subject to Best Available Control Technology (BACT) requirements for emissions of NO_x, CO, PM, SO_2, and VOC.

BACT

A control plan which addresses BACT for each of the above-mentioned pollutants has been developed. Because NO_x is the pollutant of greatest concern in the Kuparuk area, NO_x control received primary attention. Natural gas firing and the use of dry controls will constitute BACT for turbines; natural gas firing will constitute BACT for heaters.

Air Quality Review

The Prudhoe Bay area is an attainment PSD Class II area for all criteria pollutants. The results of the air quality impact analyses show that none of the National Ambient Air Quality Standards (NAAQS) or applicable PSD increments are exceeded as a result of emissions from the proposed additional facilities.

The pollutant of primary concern for this application is NO_2 for which there is an annual NAAQS limit of 100 $\mu g/m^3$. Dispersion modeling results indicate that the highest predicted NO_2 ground level concentration in the Kuparuk area due to all sources, including background and existing sources, is 57.8 $\mu g/m^3$.

Impacts on Visibility, Soils, Vegetation, and Induced Growth

The impacts on visibility, soils, and vegetation resulting from the emissions of the proposed additional facilities and impacts of induced growth will be negligible.

2.0 INTRODUCTION

2.1 Applicant Information

This application is being submitted by ARCO Alaska, Inc. (a subsidiary of Atlantic Richfield Company) (ARCO). Addresses and contacts are as follows:

Owners

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(907) 265-6951

Location of Source

Kuparuk Oil Field
Kuparuk, Alaska

Approximate Center of Kuparuk Field

Latitude: 70° 20' N

Longitude: 149° 47' W

UTM Coordinates: 401.0 km East, 7802.8 km North

2.2 Source Information

The Kuparuk Field is an onshore oil field located on the North Slope of Alaska (Figure 2-1). The proposed development area covers approximately 210 square miles, the center of which is located approximately 25 miles west of the Prudhoe Bay Field and 10 miles south of Harrison Bay on the Beaufort Sea (Figure 2-2). ARCO Alaska, Inc. is currently the sole participant and operator of the field.

In the Kuparuk Oil Field operation, produced well fluids enter a common flowline at each drill site and are heated from approximately 90°F to 130°F in the drill site heaters. The produced fluids then flow through a common flowline to production facilities, where they are separated into oil, natural gas, and water. The water goes to the produced water facilities and the gas goes to the gas processing train. The gas is used for fuel, artificial lift at the drill sites, and is compressed for reinjection into the reservoir. The produced water is injected into the water disposal well. Product oil is cooled as required, metered, and pumped through the Kuparuk Pipeline to Alyeska's Pump Station No. 1 at Prudhoe Bay.

Existing operations in the Kuparuk area are located at the Central Production Facility (CPF). In addition to turbines and heaters installed at the CPF to process hydrocarbons, existing CPF operations include an operations center consisting of sleeping, eating, and recreational facilities with associated heating, lighting, and sewage treatment.

The existing emission sources are listed in Table 2-1.

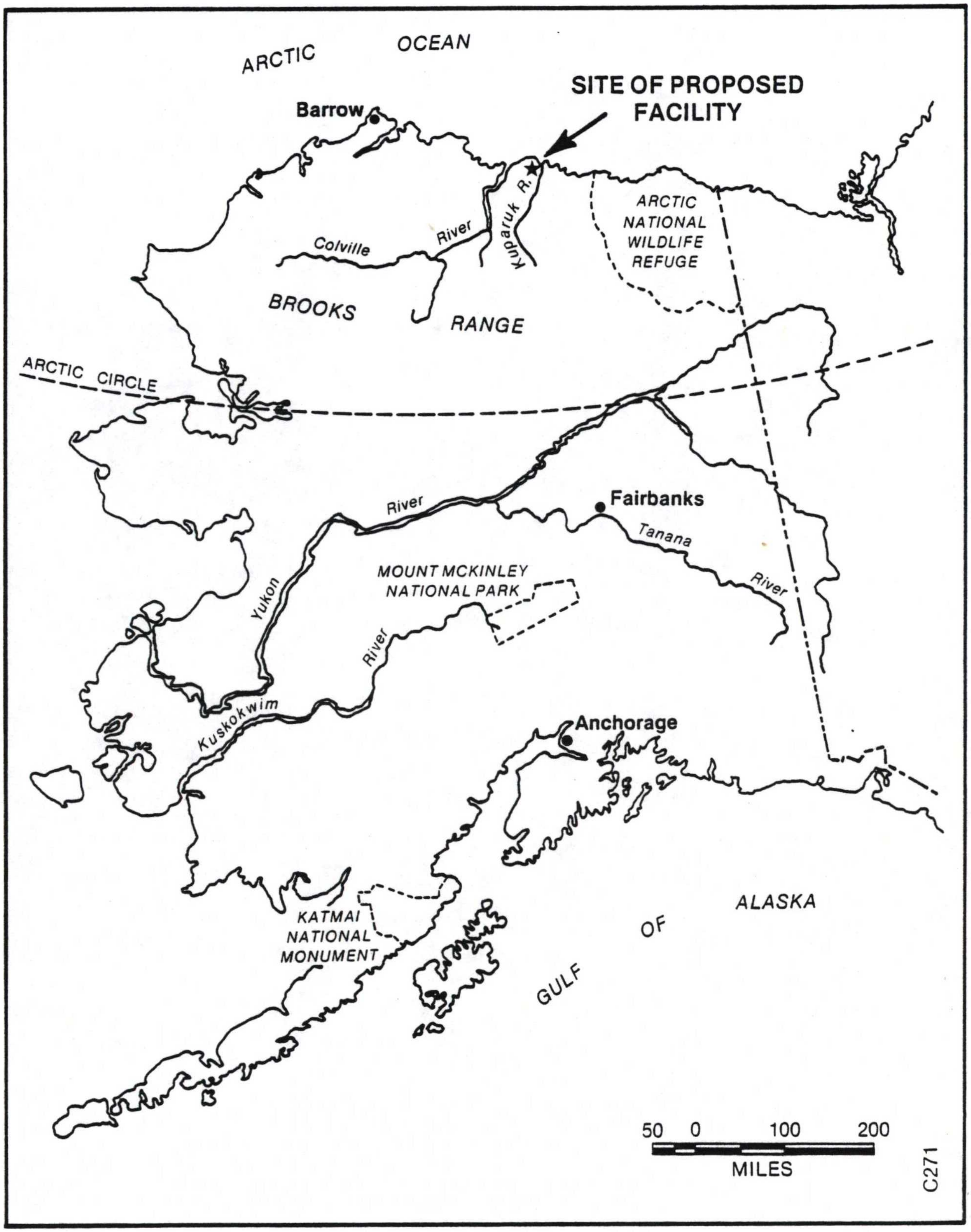


Figure 2-1. Location of the Kuparuk Area

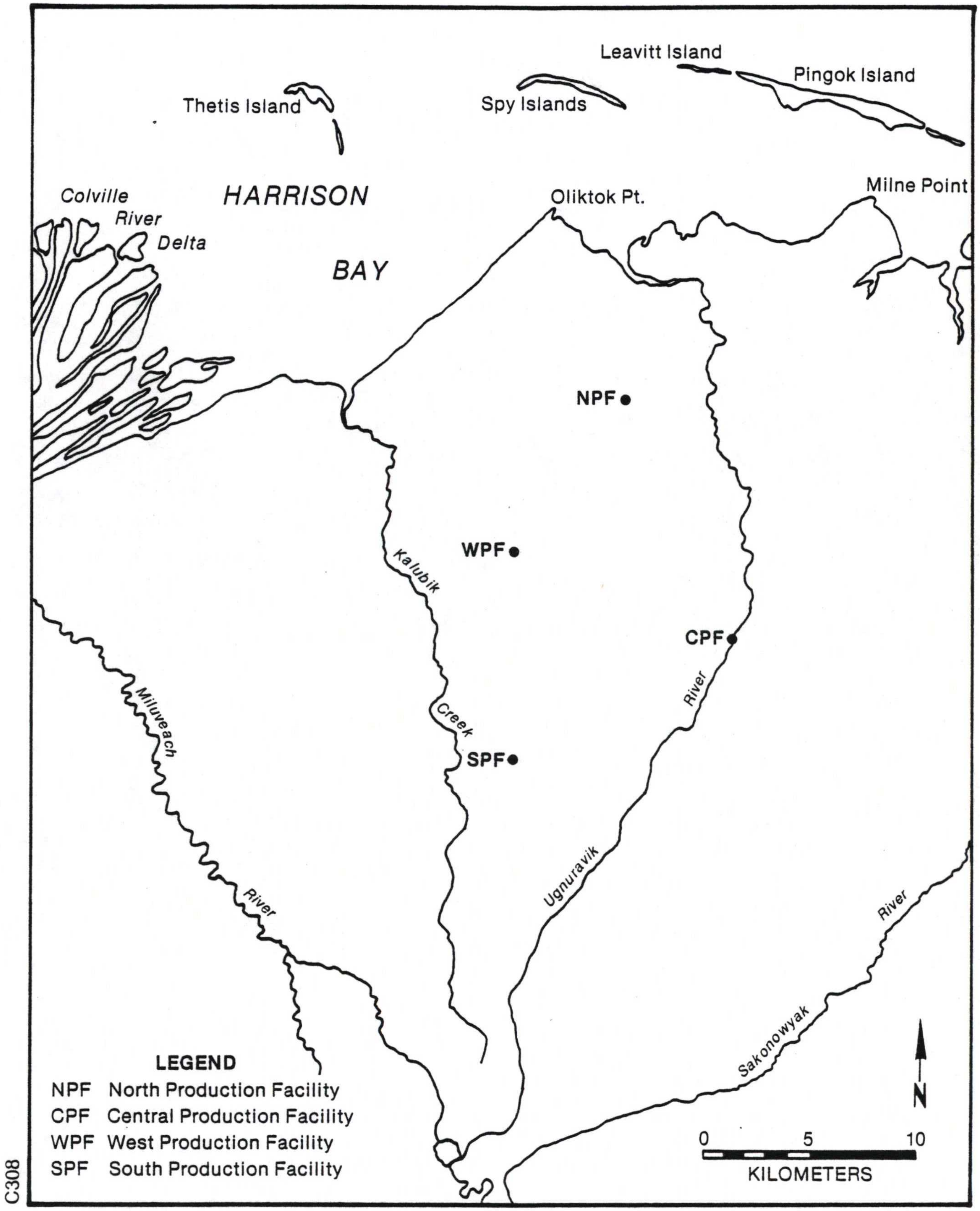


Figure 2-2. Location of Proposed Facilities in the Kuparuk Area

TABLE 2-1
EXISTING AND PREVIOUSLY LICENSED SOURCES

Location	Description
Central Production Facility	4-5 MHP Turbines
	2-14 MHP Turbines
	5-10 MMBtu/hr Heaters *
	1-20 MMBtu/hr Heater
	1-1300 lb/hr Incinerator
	1-Slop oil tank
	2-Oily waste tanks

*The 10 MMBtu/hr heaters are assigned to the production facilities for dispersion modeling purposes. In actuality they will be constructed at sites in the Kuparuk Oil Field near the Central Production Facility.

Several air pollutant emitting facilities have been licensed to operate at the CPF and are scheduled for full operation in early 1982. These include an emergency flare system, oily waste tanks and turbine compressors. Five heaters, to be located at drill sites throughout the oil field have also been licensed but are not yet installed.

Emissions and stack parameters for existing and previously licensed sources in the Kuparuk Oil Field area are listed in Appendix A.

Additional facilities will be required to increase the development of the Kuparuk Oil Field. These facilities, pertinent to this permit application, will consist of:

- Drill sites - approximately 100

- Central Production Facility (CPF) Expansion - additional turbines and heaters

- Additional Production Facilities - three additional facilities located optimally across the field for the processing of hydrocarbons and named North Production Facility (NPF), South Production Facility (SPF) and West Production Facility (WPF)

- Water Injection Facilities - located at each production facility

- Central Power Production Facilities - located at the CPF

- Crude Oil Topping Plant (COT) - located at the CPF

3.0 DESCRIPTION OF THE PROPOSED EMITTING FACILITIES

3.1 Source Descriptions

Three types of sources likely to be installed will generate or will have the potential to generate pollutants. These are:

(1) Gas-fired Turbine Prime Movers
(2) Gas-fired Heaters
(3) Crude Oil Topping Unit

Fuel used to fire the turbines and heaters will be supplied by produced natural gas (natural gas separated from the produced crude oil). Fuel gas is anticipated to have a heat rating of 1100 Btu/MCF and a composition of 78 percent C_1, 10 percent C_2, 10 percent C_3+, and an H_2S concentration of less than 20 ppm.

The proposed emission sources are listed in Table 3-1 and their respective locations are shown on Figure 2-2.

Turbines

The proposed turbines will be fired with natural gas from the Kuparuk Field. They will vary in approximate individual power ratings from 4900 horsepower to 34,000 horsepower. The turbines will be housed in buildings of varying dimensions, probably not greater than about 66 feet in height. Ducts will carry the exhaust gases through the tops of the buildings and into stacks mounted outside. The tallest stacks will extend to approximately 80 feet above ground level.

KUPARUK

TABLE 3-1

PROPOSED FACILITIES SOURCE LIST

Location	Description
Central Production Facility	3-14 MHP Turbines
	8-34 MHP Turbines
	21-10 MMBtu/hr Heaters*
	Crude Oil Topping (COT) Unit Flare
	1-40 MMBtu/hr COT heater
West Production Facility	8-4.9 MHP Turbines
	4-14 MHP Turbines
	25-10 MMBtu/hr Heaters*
	1-20 MMBtu/hr Heater
North Production Facility	8-4.9 MHP Turbines
	4-14 MHP Turbines
	25-10 MMBtu/hr Heaters*
	1-20 MMBtu/hr Heater
South Production Facility	8-4.9 MHP Turbines
	4-14 MHP Turbines
	25-10 MMBtu/hr Heaters*
	1-20 MMBtu/hr Heater

*The 10 MMBtu/hr heaters are assigned to the production facilities for dispersion modeling purposes. In actuality they will be constructed at sites throughout the Kuparuk Oil Field, yet to be determined.

Combustion turbines operate by drawing air through an intake, then compressing the air with the front-end turbine blades, and forcing the air into a combustion chamber. A very hot flame fueled by gas causes continuous rapid heating and, thus, expansion of air within the combustion chamber. This expansion of air imparts a force on the remaining sets of turbine blades, causing them to move and the shaft to rotate. The exhaust air proceeds out the stack as a combination of air, combustion products (CO_2 and H_2O), and products of endothermic reactions such as NO and CO. The gases exit at high velocity and temperature. Waste heat will be recovered from most turbine units.

Utility and Drill Site Heaters

Plans are to install one utility heater at each processing facility and one drill site heater at each drill site. These will be fired with natural gas from the Kuparuk Field. They may vary in individual heat output capacity, but present plans call for utility heaters of 20 MMBtu/hr capacity and drill site heaters of 10 MMBtu/hr capacity. The tallest heater stacks will extend approximately 80 feet above ground level. Plans are to install the utility heaters outside of buildings.

Utility heaters will be used as a secondary system to heat glycol directly for subsequent heating of building air, water, oil, and miscellaneous items. The primary source of heat will be obtained through the use of heat recovery from the gas fired turbines and utility heaters will normally be used only when turbines are down. Emissions are generated similarly to those from the turbines, but because the flame temperature in the heaters is lower than in the turbines, the NO_x yielded per unit of fuel burned is less. There is not a rapid expansion of air in the heaters, so their exhaust gases have a lower velocity in the stack.

Drill site heaters will be operated continuously to heat the produced fluids from the wellbores. These heaters are an indirect type using a glycol-water bath and will be located immediately downstream of the drill sites. These heaters will typically have stacks of about 57 feet above the ground.

Crude Oil Topping Unit

A Crude Oil Topping Unit may be constructed at the CPF to provide diesel fuel for various operations in the Kuparuk Field. A gas-fired heater will be used to heat the oil and provide space heating. The COT heater stack will extend approximately 60 feet above the ground. During the processing of diesel fuel from crude oil, some hydrocarbon vapors will be flared as a by-product through a 60 foot stack. Vapors should be emitted to this flare system at a rate of approximately 250 MSCF per day.

3.2 Operating Schedule

The proposed turbines and drill site heaters are scheduled to operate continuously all year long. No flaring of separator gases is scheduled, but infrequent operations may be necessary for emergency purposes.

3.3 Milestone Schedule

A schedule of events leading to the construction and operation of the anticipated processing facilities is shown in Figure 3-1. Various options for developing the Kuparuk Field are presently under study. Therefore, dates for starting a particular piece of equipment, equipment sizes, and equipment locations cannot be quantified completely at this time.

KUPARUK DEVELOPMENT MILESTONE CHART

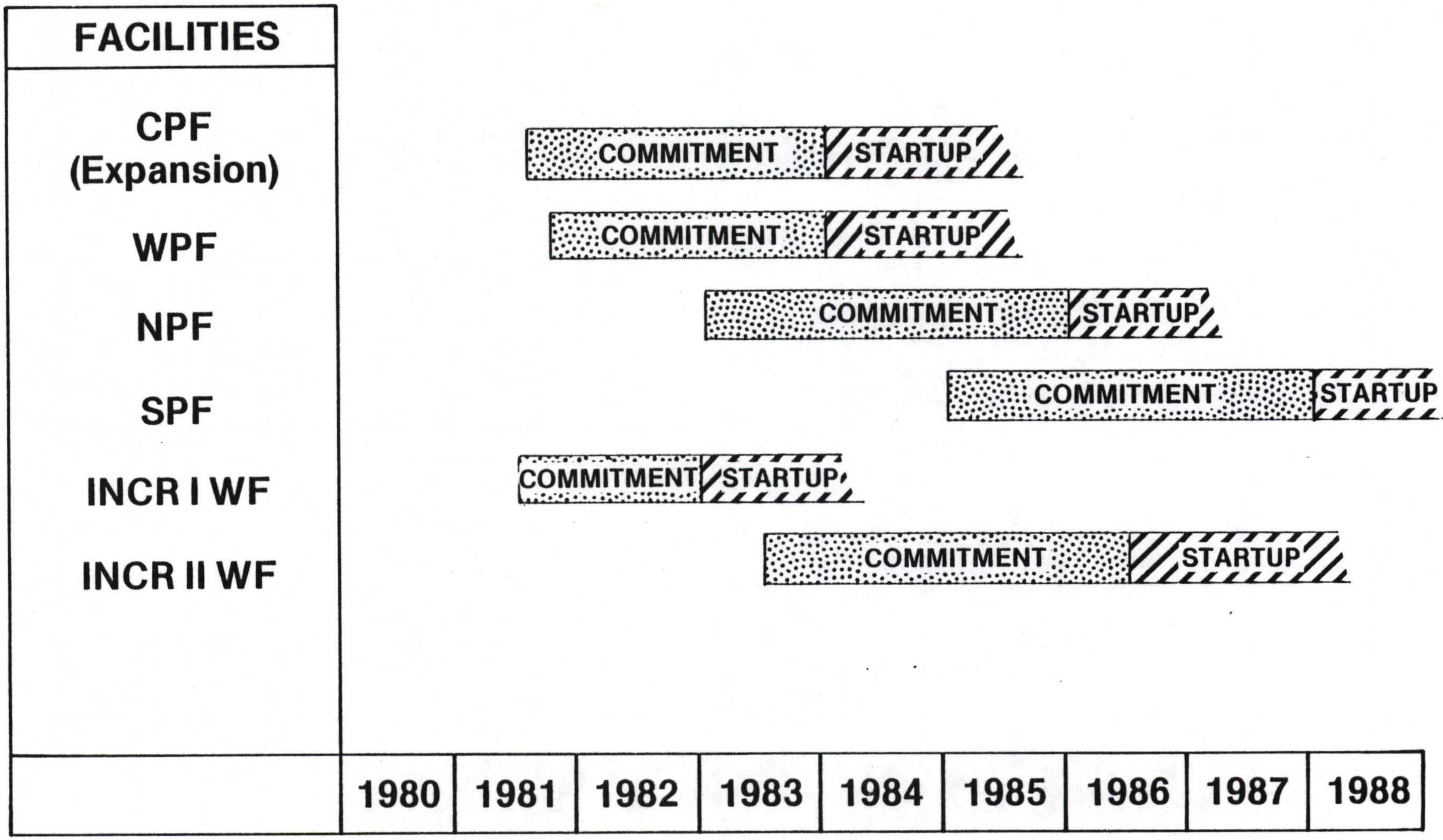


Figure 3-1. Kuparuk Development Milestone Chart

3.4 New Source Emissions and Operating Parameters

3.4.1 Methodology for Gas-Fired Turbines

The method used to calculate potential emissions for gas turbines is based on the fuel gas composition or on AP-42 emission factors. A typical fuel gas composition is presented in Appendix B. A complete emissions inventory is presented in Appendix A.

Nitrogen Oxides (NO_x)

Because of extremely high combustion temperatures, oxides of nitrogen (NO_x) are emitted in the greatest quantity from the turbines, but other pollutants will also be emitted. Table 3-2 presents potential emissions from these turbines. Worst-case stack characteristics for these units are presented in Table 3-3.

Potential emissions of nitrogen oxides are based on pormulgated New Source Performance Standards for Stationary Gas Turbines (NSPS) (Federal Register, Vol. 44, September 10, 1979, p. 52798). Combustion calcuations are performed on the fuel gas analysis (see Appendix B) with the result that one mole of fuel yields 36.27 moles of flue gas at 15 percent excess O_2 on a dry basis at 70°F. Operating parameters for gas turbines were obtained from manufacturers' data and fuel consumption rates were determined from these parameters. NO_x (as NO_2) emissions were then calculated at 150 ppmv of flue gas as specified in the NSPS. The equations used in performing calculations are shown in Appendix B.

TABLE 3-2

PROPOSED SOURCE POTENTIAL EMISSION AND STACK CHARACTERISTICS

MAP ID	Description	UTM (m) East	UTM (m) North	Potential Emissions NO_x (g/s)	SO_2 (g/s)	PM (g/s)	CO (g/s)	HC (g/s)	Stack Characteristics Height (m)	Temp °K	Diameter (m)	Velocity (m/s)
CPF	1-40 MM Btu/hr heater	401250	7804250	1.05	0.015	0.069	0.078	0.014	26.2	450	0.9	6.0
	3-14 MHP w/WHR turbines			29.1	0.15	0.63	5.8	1.05	24.4	500	2.2	22.4
	8-34 MHP w/WHR turbines			188.5	0.96	4.09	37.68	6.89	24.4	500	2.2	43.9
	21-10 MM Btu/hr heaters			5.5	0.08	0.36	0.40	0.06	17.4	450	0.8	8.2
	COT Flare			0.32	0.24	0.02	1.59	3.2	18.3	339	0.05	52.13
NPF	8-5 MHP w/WHR turbines	397000	7815750	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	4-14 MHP w/WHR turbines			38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	25-10 MM Btu/hr heaters			6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	1-20 MM Btu/hr heater			0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7
SPF	8-5 MHP w/WHR turbines	391250	7799250	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	4-14 MHP w/WHR turbines			38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	25-10 MM Btu/hr heaters			6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	1-20 MM Btu/hr heater			0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7
WPF	8-5 MHP w/WHR turbines	391500	7808750	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	4-14 MHP w/WHR turbines			38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	25-10 MM Btu/hr heaters			6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	1-20 MM Btu/hr heater			0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7

TABLE 3-3

STACK PARAMETERS AND OPERATING CONDITIONS

ASSUMED FOR SOURCES MODELED[1]

Map ID	Description	Modeled Stack Characteristic Assumptions
CPF	4-4.9 MHP turbines	5 MHP w/WHR
CPF	5-14 MHP turbines	14 MHP w/WHR
CPF	8-34 MHP turbines	34 MHP w/WHR
CPF	26-10 MM Btu/hr heater[2]	10 MM Btu/hr heater
CPF	1-20 MM Btu/hr heater	20 MM Btu/hr heater
CPF	1-40 MM Btu/hr heater	40 MM Btu/hr heater
WPF	8-4.9 MHP turbines	5 MHP w/WHR
WPF	4-14 MHP turbines	14 MHP w/WHR
WPF	25-10 MM Btu/hr heater[2]	10 MM Btu/hr heater
WPF	1-20 MM Btu/hr heater	20 MM Btu/hr heater
NPF	8-4.9 MHP turbines	5 MHP w/WHR
NPF	4-14 MHP turbines	14 MHP w/WHR
NPF	25-10 MM Btu/hr heater[2]	10 MM Btu/hr heater
NPF	1-20 MM Btu/hr heater	20 MM Btu/hr heater
SPF	8-4.9 MHP turbines	5 MHP w/WHR
SPF	4-14 MHP turbines	14 MHP w/WHR
SPF	25-10 MM Btu/hr heater[2]	10 MM Btu/hr heater
SPF	1-20 MM Btu/hr heater	20 MM Btu/hr heater

[1] For existing, previously licensed and proposed Kuparuk sources.

[2] 100 drill site heaters, 25 at each facility.

Hydrocarbons (HC) and Carbon Monoxide (CO)

Potential emissions of hydrocarbons (HC), and carbon monoxide (CO) are based on AP-42 emission factors for gas turbine compressor engines, Table 3.3.2-1 (EPA, AP-42, August 1977, p. 149). HC emissions are given as total hydrocarbons and volatile organic compounds (VOC) emissions should only comprise about 5-10 percent of this total (EPA, AP-42, August 1977, p. 149). The emission calculations are presented in Appendix B.

Particulate Matter (PM)

Emission factors for particulates from gas turbines are listed as not available in Table 3.3.2-1 of AP-42. Consequently, the factor from Table 3.3.1-2, composite emissions factors for electric utility gas turbines was used (EPA, AP-42, August 1977, p. 146).

Sulfur Dioxide (SO_2)

The emission factor used is based on an estimated fuel gas composition of 20 ppm H_2S, a maximum heat rate of 9433 Btu/hp-hr and conditions of 70°F and 1 atmosphere. Potential emissions are listed in Table 3-2. Worst-case stack characteristic assumptions are presented in Table 3-3. The detailed emissions rate calculations are presented in Appendix B.

3.4.2 Methodology for Gas-Fired Heaters

The potential emissions of NO_x, PM, CO, and HC from gas-fired heaters are based on AP-42 emission factors for natural gas combustion sources, Table 1.4-1 (EPA, AP-42, August 1977, p. 39). The emission calculations are presented in Appendix B.

The potential emissions and worst-case stack characteristics are reported in Table 3-2 and Table 3-3, respectively. A complete emissions inventory is presented in Appendix A.

Sulfur Dioxide (SO_2)

The sulfur dioxide emissions calculations are based on an estimated fuel gas composition of 20 ppm H_2S and a lower heating value of the Prudhoe Bay gas of 1100 Btu/scf (298°K 1 atmosphere). Worst-case stack characteristics are shown in Table 3-2. The emission rate calculation is shown in Appendix B.

Crude Oil Topping Unit

AP-42 publishes no flare emission factors. Therefore AP-42 emission factors for natural gas combustion, Table 1.4-1, were used for PM, CO, HC, and NO_2. Crude oil vapors are considerably heavier than natural gas and contain more sulfur than the sulfur content assumed for natural gas in AP-42. Therefore, to conservatively estimate the SO_2 emissions from the Crude Oil Topping Unit (COT) a percent sulfur fuel content must be assumed. The Oil and Gas Journal, January 7, 1976, publishes a sulfur content of 1.04 percent for North Slope Crude. Detailed calculations based on this fuel sulfur content are shown in Appendix B.

4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 Site Topography and Land Use

The land use of the Kuparuk area is predominantly rural, as determined by the urban/rural classification scheme described in the proposed Revisions to the Guideline on Air Quality Models (EPA, 1980). Therefore use of rural modeling techniques is appropriate for the region.

The topography and land use of the Kuparuk area are virtually identical to that of the Prudhoe Bay region, as described in detail in Section 4.1 of the Prudhoe Bay Unit Owners' Waterflood Application (1979). Figure 4-1 illustrates the topography of the Kuparuk area.

4.2 Soils and Vegetation

A description of the soil characteristics and vegetation communities in the Kuparuk and Prudhoe Bay areas is presented in Section 9.0 of the Prudhoe Bay Unit Owners' Waterflood Application (1979).

4.3 Climate

The general climate of the Kuparuk and Prudhoe Bay areas, including patterns of precipitation, snowfall, temperature, fogging, and icing, is best determined from an examination of National Climatic Center and National Weather Service data sources. Such a description is presented in Section 4.2 of the Prudhoe Bay Unit Owners' Waterflood Application (1979).

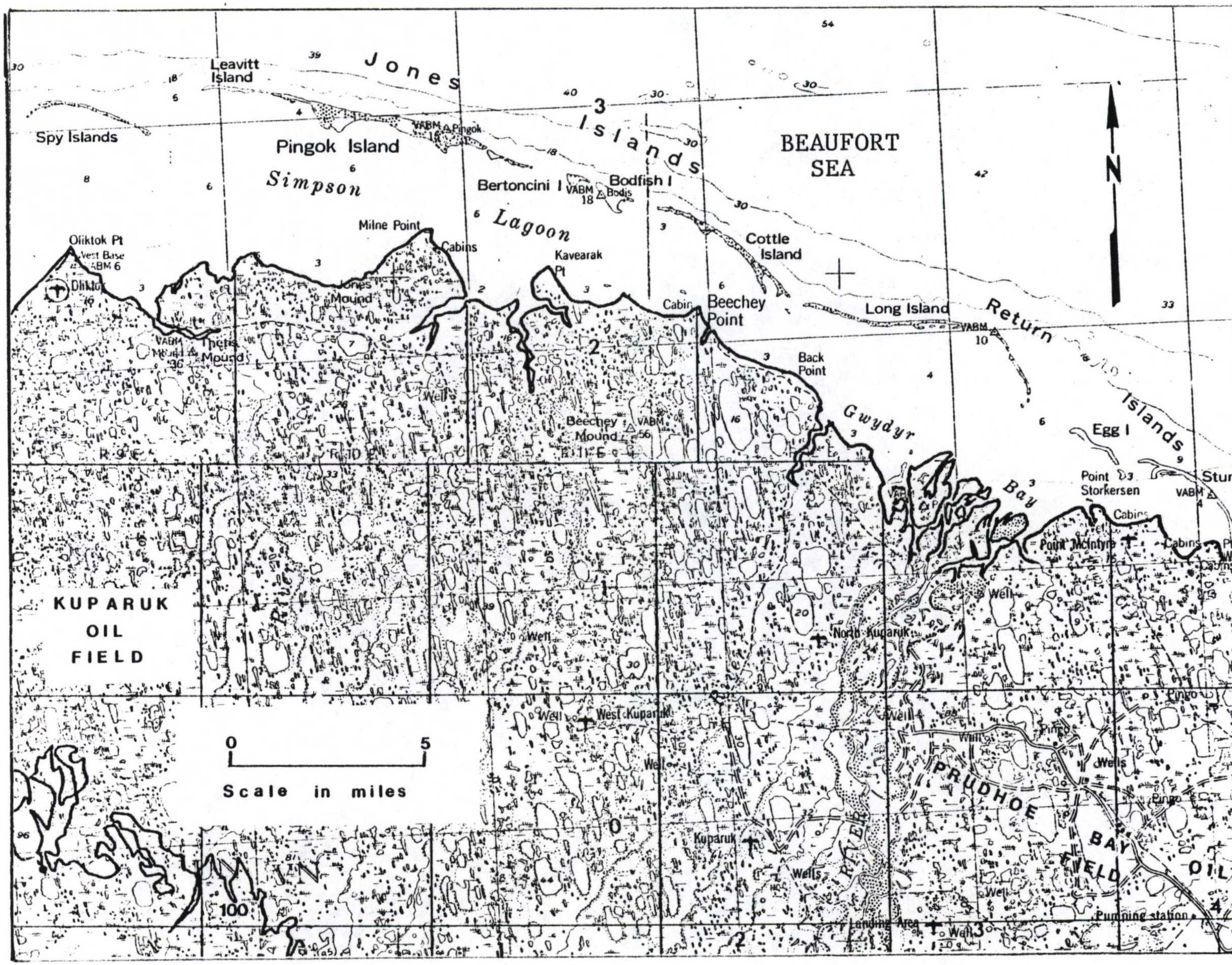
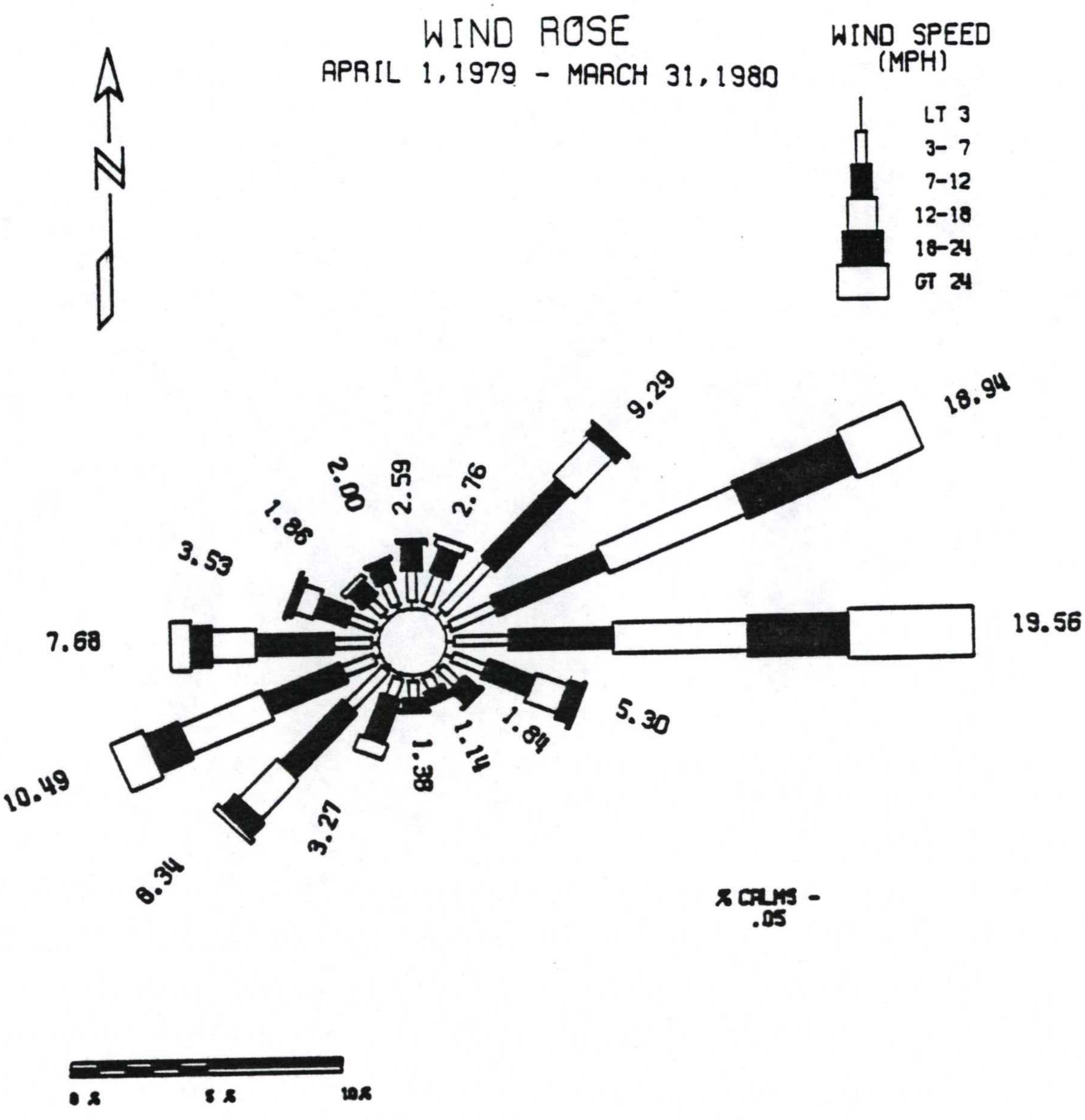


Figure 4-1. Topography of the Site Area

A one year air quality and meteorological monitoring program was conducted in the Prudhoe Bay area between April 1, 1979 and March 31, 1980. Wind direction, wind speed, as well as stability patterns and distributions, have been determined from data collected during this program at the 10-meter level of the two monitoring stations and at the instrumented tower. This program is described in more detail in Section 4.4 of the Waterflood Application.

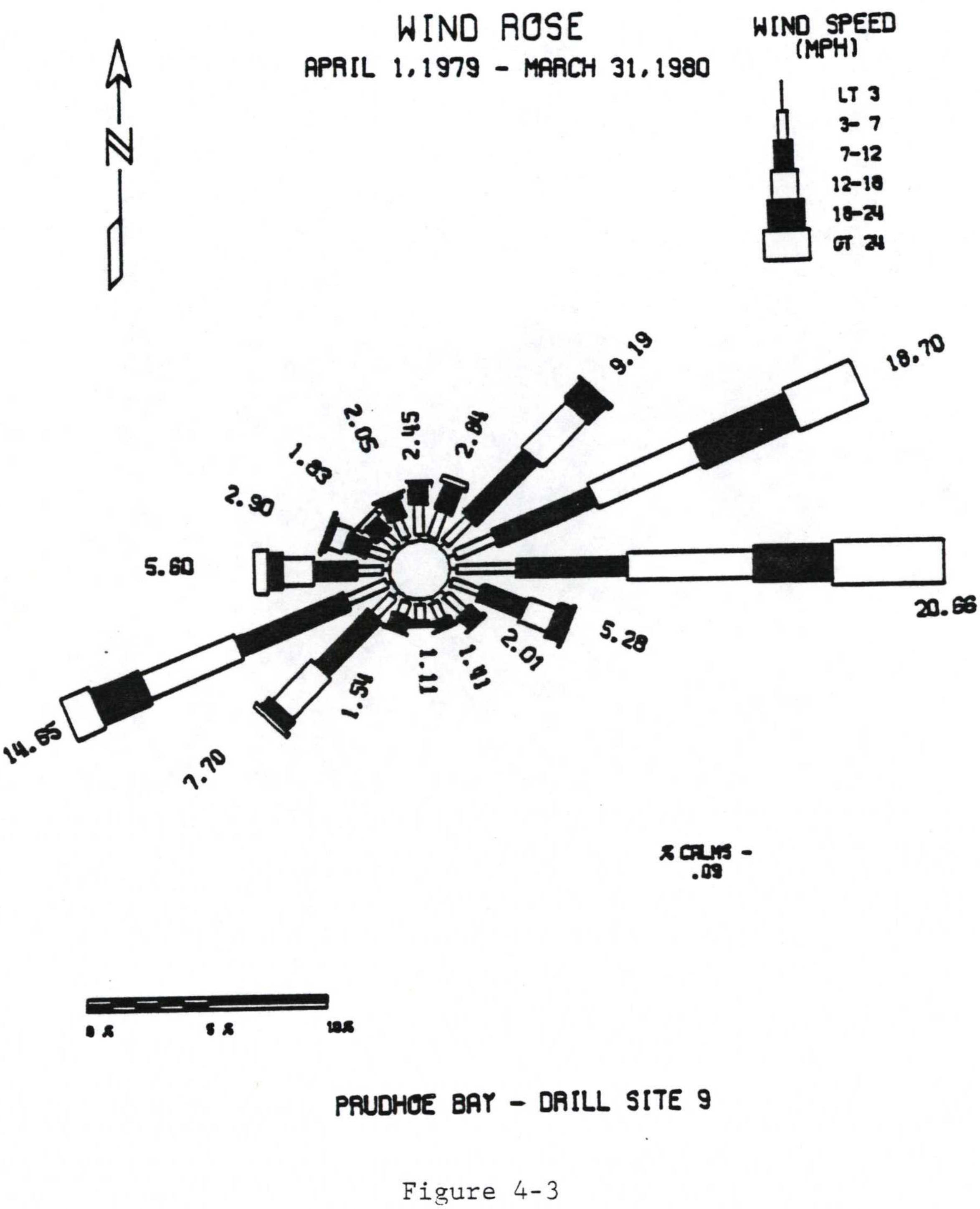
The annual wind roses for Well Pad A and Drill Site 9 (based on one year of data) for Prudhoe Bay are presented in Figures 4-2 and 4-3. The most frequent wind directions observed at each of the Prudhoe Bay monitoring sites were from the east and east-northeast (about 40 percent of the time) with a secondary maximum from the west-southwest (about 10 to 15 percent of the time). The annual wind roses look similar to the 1976 wind rose for nearby Deadhorse Airport. (The Deadhorse wind rose is presented in Section 4.0 of the Prudhoe Bay Unit Owner's Waterflood Application and in Appendix F of this application.) The average wind direction is from the east to east-northeast for most of the year except for November through February when the flow changes to a direction from the southwest to west-southwest.

The annual average wind speed was 13.3 miles per hour (mph) at Well Pad A and 13.5 mph at Drill Site 9 for the monitoring period. During the same period, Point Barrow reported an average speed of 13.2 mph. The average speed for Barter Island could not be computed because of missing wind data. In general, the monthly average wind speeds showed the same trends at all of the sites. The monthly averages show consistently high speeds, over 10 mph, but they also show a fair amount of geographic variability, especially in January and December.



PRUDHOE BAY - WELL PAD A

Figure 4-2



WIND ROSE
APRIL 1,1979 - MARCH 31,1980
WIND SPEED
(MPH)
LT 3
3- 7
7-12
12-18
18-24
GT 24
N
9.19
18.70
2.05
2.45
2.84
1.83
2.90
5.60
20.66
2.01
5.28
1.11
1.41
1.54
14.65
7.70
% CALMS -
.09
PRUDHOE BAY - DRILL SITE 9

Figure 4-3

Another comparison can be made with 1976 wind data from the nearby Deadhorse Airport. For that year the average speed was 12.8 mph which approximates the Well Pad A and Drill Site 9 speeds (13.3 and 13.5 mph) for 1979-1980.

Due to the similarities in meteorological conditions at Prudhoe Bay, Deadhorse, Barter Island, and Barrow, and the flat terrain at all locations, the Prudhoe Bay meteorological data form an excellent basis for describing the meteorology of the Kuparuk area.

The annual frequency distributions of the six stability classes for Prudhoe Bay are presented in Table 4-1. The processing of the on-site meteorological data to generate the annual frequency distribution is described in Appendix C. The mean wind speed associated with each stability class is also given. This table indicates that neutral stability class conditions occur about 62 percent of the time at Prudhoe Bay. According to Pasquill's standard method for determining stability classes, neutral conditions generally result from moderate to strong winds and cloudy conditions (National Climatic Center, 1958 to 1964). Seasonal and annual joint frequency distributions for wind speed, wind direction, and stability class, calculated from the Prudhoe Bay data, are presented in Appendix E.

TABLE 4-1

ANNUAL FREQUENCY DISTRIBUTION OF PASQUILL STABILITY CLASSES AND WIND SPEEDS AT PRUDHOE BAY

Stability Class	Definition	Annual Frequency (%)	Average Wind Speed (mph)
A	Extremely Unstable	9.84	6.1
B	Unstable	6.28	8.4
C	Slightly Unstable	8.76	11.3
D	Neutral	62.23	14.1
E	Slightly Stable	7.08	6.7
F	Stable to Extremely Stable	5.81	3.8

Source: Radian Corporation, Air Quality and Meteorological Monitoring Study at Prudhoe Bay, Alaska (April 1, 1979 to March 31, 1980) October 1980.

4.4 Existing Air Quality

Determination of the impact of emissions from all sources (including the proposed facilities) in the Kuparuk Oil Field area on the National Ambient Air Quality Standards (NAAQS) requires a determination of the existing air quality of the area. This determination also illustrates the current status of compliance with the National Ambient Air Quality Standards.

Background levels, estimated from current air quality monitoring data, can be added to concentrations predicted for all the sources to predict total air quality impacts. For the purposes of this document, the term "background" refers to the contributions to total air quality from all anthropogenic and natural sources outside of or upwind from the Kuparuk River area.

For the purposes of the PSD study, air quality data collected at two monitoring sites in the Prudhoe Bay area were used to characterize existing and background air quality levels. Beginning on April 1, 1979 until March 31, 1980, the Prudhoe Bay area operators conducted a one-year air quality and meteorological monitoring program. The network consisted of two remote sites designed to collect both air quality and meteorological parameters and a 200-foot communications tower instrumented with meteorological sensors. The remote monitors were located at Drill Site 9 and Well Pad A and the instrumented tower was located at the SOHIO Base Operating Camp (Figure 4-3).

The following air quality and meteorological parameters were collected at each remote site:

1. Oxides of Nitrogen (NO_x)
2. Nitric Oxide (NO)
3. Nitrogen Dioxide (NO_2)
4. Sulfur Dioxide (SO_2)
5. Ozone (O_3)
6. Carbon Monoxide (CO)
7. Total Hydrocarbons (THC)
8. Methane (CH_4)
9. Non-Methane Hydrocarbons (THC-CH_4)
10. Wind Speed (33 feet)
11. Wind Direction (33 feet)
12. Temperature (33 feet)
13. Total Suspended Particulates (TSP)

In addition, precipitation and visibility were measured at Drill Site 9 (Site 2 in Figure 4-4), the upwind site. Temperature layering heights and wind profiles were measured at Well Pad A (Site 1 in Figure 4-4), the downwind site, using an ECHOSONDE® acoustic sounder system. These ECHOSONDE® temperature structure data were used in estimating on-site mixing heights for the Prudhoe Bay area.

The following meteorological parameters were monitored at the 60 meter communications tower site:

Temperature	33-foot level
Temperature	33 - 200-foot level
Wind Speed	146-foot level
Wind Direction	146-foot level
Wind Speed	200-foot level
Wind Direction	200-foot level
Wind Direction Horizontal Standard Deviation	200-foot level

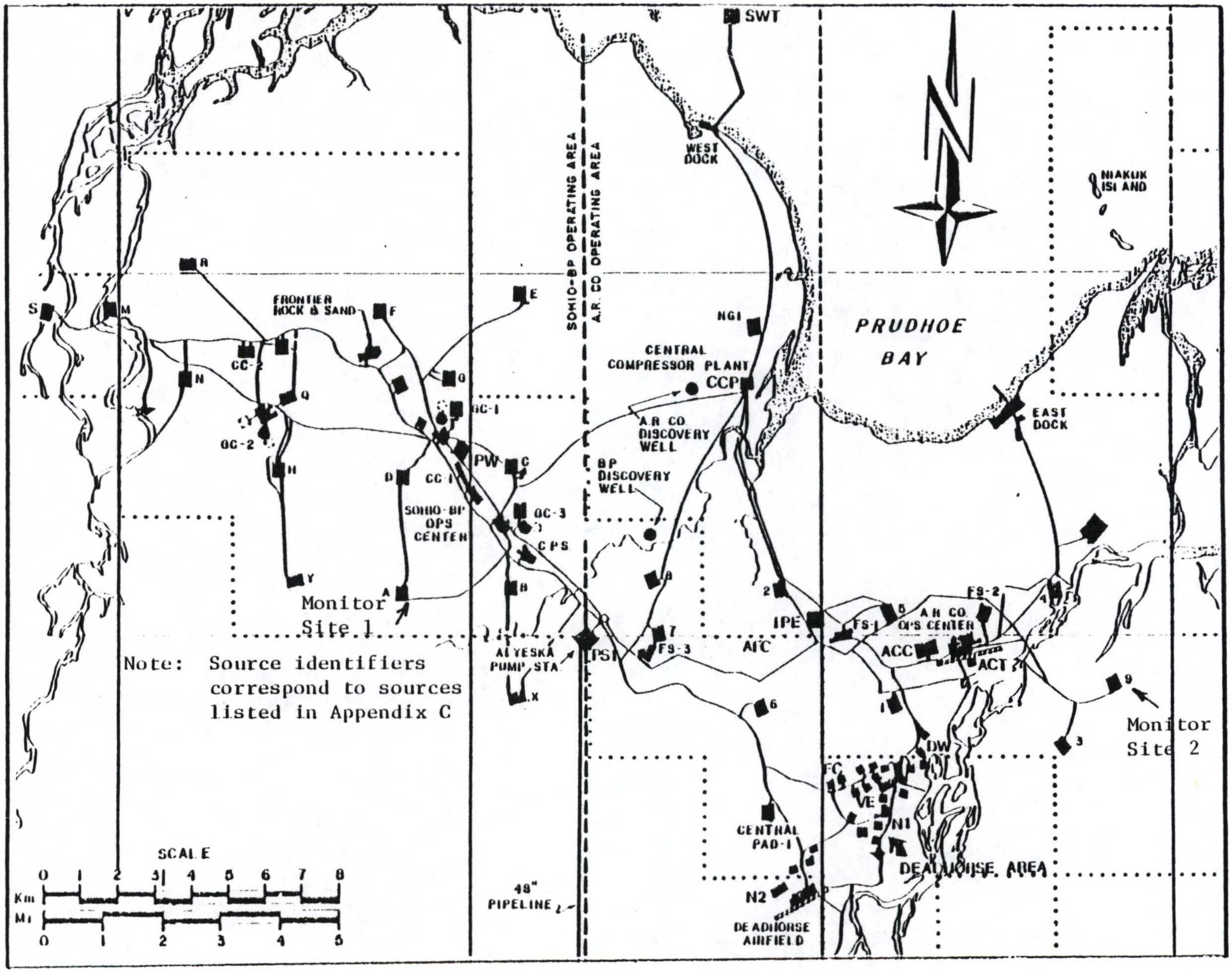


Figure 4-4. Location of Air Quality Monitors in the Prudhoe Bay Unit

To support the monitoring activities, a monitoring plan entitled Ambient Air Quality and Meteorological Monitoring Plan for Prudhoe Bay, Alaska was submitted to EPA Region X and the Alaska DEC in late 1978. This monitoring program is being used to satisfy PSD-related monitoring requirements. The monitoring plan demonstrated that all siting, operating, quality assurance, and data validation procedures employed in the network operation corresponded to guidelines established by the Environmental Protection Agency.

The annual monitoring report entitled Air Quality and Meteorological Monitoring Study for Prudhoe Bay, Alaska has been submitted in support of the Prudhoe Bay Unit PSD IV permit application. This report covers the period from April 1, 1979 until March 31, 1980 and presents a summary of air quality and meteorological parameters.

Table 4-2 reports maximum and mean levels of NO_2, TSP, SO_2, CO, and ozone (O_3) measured during the 12 month monitoring period. Examination of this table shows that measured levels for all pollutants are well below those concentrations allowed by the National Ambient Air Quality Standards. The results of the monitoring program as presented in this table support the current designation of the area as being in attainment of the NAAQS for criteria pollutants. Even if the highest pollutant levels measured during the monitoring program were added to the predicted levels of NO_2, TSP, SO_2, CO, and O_3 resulting from all sources in the Kuparuk area, the NAAQS would not be exceeded.

Background pollutant levels for use in determining total air quality impacts on NAAQS were estimated from the data collected during the Prudhoe Bay monitoring program. To eliminate the influence of existing Prudhoe Bay area sources on the

TABLE 4-2

MEASURED POLLUTANT LEVELS ($\mu g/m^3$)

IN THE PRUDHOE BAY/KUPARUK AREA

Pollutant	Monitor Location: Drill Site 9	Monitor Location: Well Pad A	National Ambient Air Quality Standards: Primary	National Ambient Air Quality Standards: Secondary
NO_2				
Arithmetic Mean*	3.5	4.0	100 (Annual)	100 (Annual)
TSP				
Geometric Mean*	6.7	11.4	75 (Annual)	60 (Annual)
24 Hour Maximum+	64	119	260	150
SO_2				
Arithmetic Mean*	0.4	0.5	80 (Annual)	---
24 Hour Maximum+	9.5	9.3	365	---
3 Hour Maximum+	13.0	25.3	---	1300
CO				
8 Hour Maximum+	946	856	10,000	10,000
1 Hour Maximum+	3430	3120	40,000	40,000
O_3				
1 Hour Maximum++	113	113	235	235

*Period of Record (4/1/79 - 3/31/80)

+Not to be exceeded more than once per year.

++Ozone standard is attained if the expected number of days per calendar year with maximum hourly average concentrations is ≤one.

monitors, only those periods during which the monitors were upwind of all Prudhoe Bay sources were selected for use in the background estimation. For each pollutant, the mean of all concentrations measured during the selected periods was chosen as the background applicable for all averaging times with the exception that it is unreasonable to expect the mean background monitored concentration to exceed the mean annual monitored concentration. It was assumed that measurements occurring during periods of east-northeast winds at Drill Site 9 and west-southwest winds at Well Pad A would be representative of background conditions in the Prudhoe Bay and Kuparuk areas.

Based on these assumptions and methods, background concentrations were estimated for the two monitor sites and are shown in Table 4-3.

TABLE 4-3

ESTIMATED BACKGROUND AND MONITORED POLLUTANT LEVELS

	Pollutant Concentration ($\mu g/m^3$)				
	NO_2	TSP	SO_2	CO	O_3
Annual Monitored Values					
For Source Segregation					
East-Northeasterly Winds - Drill Site 9	1	15	*	100	51
West-Southerwesterly Winds - Well Pad A	2	5	*	190	51
Total Annual Mean					
Well Pad A	4	11	*	171	48
Drill Site 9	4	7	*	133	51
Estimated Background Levels**	2	11	--	171	51

*Below detectability limit of instrument.

**Background levels estimated by using monitored data as indicated by encircled values in table.

5.0 BEST AVAILABLE CONTROL TECHNOLOGY

Prevention of Significant Deterioration (PSD) Regulations promulgated by the USEPA on August 7, 1980 state that a project must apply Best Available Control Technology (BACT) to each pollutant regulated under the Clean Air Act for which a proposed facility emits a "significant" amount. "Significant" in terms of net emissions increase or potential to emit means an emission rate for a proposed source that would equal or exceed the values shown in Table 5-1. For comparison, the total potential emissions for the proposed facilities are also shown in Table 5-1.

Net emission increases for CO, NO_x, SO_2, PM, and VOC from the proposed new sources exceed the significant levels. Therefore, BACT will be applied to control these emissions from the proposed facilities.

5.1 Proposed Controls Representing BACT

An analysis has been performed to determine BACT for the proposed facilities in a manner consistent with national and EPA Region X guidelines. The primary emission sources are gas-fired turbines and heaters. BACT for these sources was determined according to the precedents set in the Unit Owner's PWI/LPS/AL and Waterflood permits (Permit Nos. PSD-X-80-09 and PSD-X-81-01). The controls proposed as BACT are summarized below:

Turbines

Natural gas firing and the use of dry (internal combustion) controls is proposed as BACT.

TABLE 5-1

NET EMISSIONS INCREASES AND SIGNIFICANT LEVELS

FOR ADDITIONAL KUPARUK OIL FIELD SOURCES

Pollutant	Net Emissions Increase (t/y)	Significant Level (t/y)
CO	3,006	100
NO_x	15,402	40
SO_2	99	40
PM	373	25
VOC	64	40*

*VOC (Volatile organic compound) emissions were conservatively assumed to be 10 percent of total hydrocarbon emissions.

Heaters

Natural gas firing is proposed as BACT.

Other Facilities

In addition to the major emission sources (turbines and heaters), a refuse incinerator and a flare are included in the proposed facility. The incinerator will combust about 1300 pounds per hour of general refuse. The flare will combust the off-gases from the small crude oil topping unit. No controls are proposed as BACT for the crude oil topping unit and incinerator.

5.2 Alternative Systems Capable of Achieving Lower Emission Rates and Reasons for Their Rejection

5.2.1 Combustion Turbines

One of the best systems for turbines, from an NO_x emissions limitation standpoint, is the injection of water or steam (EPA, September 1977, p. 4-69). However, this control method is highly impractical on the north slope from the standpoint of environmental impacts, economic impacts, energy impacts, and engineering feasibility. The associated problems stem chiefly from the scarcity of freshwater, the extreme cold, and the fragility of the tundra. Because of these problems, extensive documentation has been compiled to support using dry NO_x controls for Prudhoe Bay combustion-turbines. This documentation is summarized in correspondence dated August 15, 1978, from W. P. Metz, Senior Environmental Engineer, Atlantic-Richfield Company, Alaska Region, to Mr. Paul Boys, U.S. Environmental Protection Agency, Region X.

The most promising systems from the standpoint of minimizing NO_x emissions from combustion-turbines, while maintaining a high fuel-to-power efficiency, are the dry controls being incorporated into combustion chamber design. These controls are effective in reducing thermal-NO_x production, and when combined with a fuel containing little or no organic nitrogen, this system will meet the 150 ppmv limit stipulated by the proposed NSPS for combustion-turbines in rural petroleum production facilities (Federal Register 1978, p. 26385).

A low NO_x emissions rate is not the only reason for choosing natural gas firing as representing BACT. If this analysis were to include firing with oil, it would show that oil firing would not only result in higher NO_x emissions, but also higher SO_2 and particulate emissions and would be less economical.

There are no superior demonstrated alternatives to gas-firing for reducing particulate emissions from combustion-turbines. Gas-firing represents the best available particulate emission control technology.

Hydrocarbon (HC) and carbon monoxide (CO) emissions from turbines can be decreased by increasing the flame temperature and the combustion chamber residence time, but this dramatically increases NO_x emissions (EPA, September 1977, pp. 3-104). Because of the relatively large quantities of NO_x produced compared to those of HC and CO, such a trade-off would not be justifiable. Therefore, "no control" represents BACT for CO and HC.

5.2.2 Process Heaters

BACT for the process heaters has been determined to be the use of natural gas (an intrinsically low-polluting fuel) along with normal good combustion practice and no air preheat. Use of natural gas will reduce the emissions of particulates and oxides of sulfur (SO_x) substantially, and will reduce oxides of nitrogen (NO_x) somewhat.

No alternative controls are available to reduce particulates, CO, HC, or SO_x below the levels achieved by firing natural gas. There are several systems which can theoretically be used to further reduce NO_x emissions, but these systems are not warranted on the small heaters proposed for this facility (Evans, January 1978; Siddiqi, October 1976, pp. 94-97).

NO_x emissions from heaters can be further controlled by use of low-excess-air firing, off-stoichiometric combustion, low-NO_x burners, flue gas recirculation, and stack gas treating. Low-NO_x burners are the most commonly used. It was determined in the BACT analysis for the PWI/LPS/AL and Waterflood permits (Permit Nos. PSD-X-80-09 and PSD-X-81-01) that low-NO_x burners would be used on process heaters with a heat input greater than 43 MMBtu/hr, and that natural gas firing alone would suffice as BACT for heaters smaller than 43 MMBtu/hr. This guideline was used to determine BACT for the heaters at the proposed new facilities.

5.3 References for Section 5

Environmental Protection Agency, Standards Development Branch, Standards Support and Environmental Impact Statement, Vol. 1, Proposed Standards of Performance for Stationary Gas Turbines, EPA 450/2-77-017a, Research Triangle Park, N.C., September 1977, p. 3-104, p. 4-96, and p. 4-97.

Evans, R. M. et al., Control Techniques for Nitrogen Oxides Emissions from Stationary Sources, Final Report, 2nd Edition. EPA Contract No. 68-02-2611, Task 12, EPA 450/1-78-001.

Federal Register, Vol. 43, No. 118, June 19, 1978, p. 26385.

Metz, W. P., Senior Environmental Engineer, Atlantic-Richfield Company. Personal Correspondence to Mr. Paul Boys, U.S. E.P.A., Region X, August 15, 1978.

Siddiqi, A. A., J. W. Tenini, and L. D. Killion, "Control NO_x Emissions from Fixed Fireboxes," Hydrocarbon Processing October 1976, pp. 94-97.

6.0 AIR QUALITY IMPACT ANALYSIS

6.1 Analysis Methodology

Atmospheric dispersion modeling techniques, recommended in the 1980 proposed EPA modeling guidelines were used to predict the total air quality impacts of the proposed equipment additions to the Kuparuk Oil Field. Annual modeling was performed using the rural version of the Industrial Source Complex Long Term (ISCLT) model (Bowers, et al., 1979), and short-term modeling (24-hour averaging times or less) was performed using the rural version of the Industrial Source Complex Short Term (ISCST) model. In the application of all these models the building wake effects option was used, and the rural model of the model was exercised.

To expedite the permit application review, the ISCLT and ISCST models were used, as required by EPA Region X. These models, however, have not been subjected to comprehensive technical review and "debugging". In addition, their applicability for use in the Kuparuk area for modeling turbines and heaters, especially with the building wake effects option included, has not been conclusively demonstrated. The building wake effect option may be very conservative when applied to the Kuparuk facilities, in that these facilities are built on pilings six to eight feet off the ground in order to minimize snow drifting.

For carbon monoxide, the proposed EPA short-term screening model, PTPLU, was applied, with resulting calculated ambient impacts so low that more detailed modeling applications were considered to be unnecessary. Because of the very low monitored concentrations of ozone in the area, and low sun angles, photochemical modeling of non-methane hydrocarbon emissions was considered to be inappropriate. Therefore, the potential impacts of hydrocarbon emissions on ozone characteristics were estimated through examination of Prudhoe Bay area monitoring results.

The ISCLT model was used to estimate the impacts of the proposed sources alone and in conjunction with existing and previously licensed sources on annual average concentrations of NO_2, SO_2, and TSP. ISCLT modeling results for NO_x and measured ozone concentrations were examined with the ozone limiting method (described in the proposed 1980 EPA modeling guidelines) to determine maximum NO_2 levels in refined analyses. The ISCST model was used for calculations of 3-hour and 24-hour SO_2 concentrations and 24-hour TSP concentrations. Prudhoe Bay ambient air monitoring network data were used to estimate the contributions to total ambient short-term and long-term concentrations from background sources (Section 4.4). The impacts of all existing, previously permitted, and proposed sources in the Prudhoe Bay area were predicted with the dispersion models.

Meteorological data used in the ISC modeling were those obtained from the Prudhoe Bay area PSD monitoring network, as described in Section 4.3. These data are the most representative source of wind and stability patterns in the Kuparuk area because of the close proximity of the Prudhoe Bay unit to the Kuparuk Oil Field (the Kuparuk area Central Production Facility is 36 km west-northwest of Prudhoe Bay Well Pad A), and because of strong similarities in terrain, land use, and distance from the Beaufort Sea between the two areas. Therefore, Prudhoe Bay air quality and meteorological monitoring data were used in describing baseline conditions and in modeling air quality impacts.

For annual modeling, a joint frequency distribution of wind speed, wind direction, and stability class for a one-year period (STAR deck) was used as meteorological input. The stability classes were calculated using the modified sigma theta method (Proposed Revisions to EPA Guidelines on Air Quality Models, October 1980). In the application of this method, stable conditions occurring at wind speeds greater than 11 knots were converted to stability Class D. For short-term modeling, pre-processed hourly meteorological data from the Prudhoe Bay monitoring network were input to the ISCST model. Meteorological data processing and dispersion model features are described in more detail in Appendices C and D. The representativeness of the Prudhoe Bay meteorological data is discussed in Appendix F.

Emissions sources listed in Appendix A were modeled in the annual and short-term ISC analyses. For all sources, estimated building heights and widths associated with each stack were also input to the model. All existing and previously permitted point sources in the Prudhoe Bay area were considered in the modeling analyses, although for some pollutants and averaging times the impact of their emissions were shown to be less than EPA's established significance levels.

6.2 Initial Screening

6.2.1 Annual - NO_x, SO_2, TSP

Potential emissions of NO_x, SO_2, and PM from the proposed Kuparuk Oil Field sources were modeled with the rural mode of ISCLT to determine the potential for significant impacts for the different pollutants. The results of this modeling analysis are presented in Table 6-1.

TABLE 6-1

RESULTS OF SCREENING MODELING ANALYSES

FOR EMISSIONS FROM PROPOSED KUPARUK OIL FIELD SOURCES

Pollutant	Averaging Time	Maximum Predicted Concentration ($\mu g/m^3$)	Significance Level* ($\mu g/m^3$)
NO_x	Annual	43.81	1
SO_2	Annual	2.01	1
	24-hour	10.08	5
	3-hour	67.44	25
TSP	Annual	1.32	1
	24-hour	15.51	5
CO	8-hour	<757	500
	1-hour	757	2000

*As defined in 1977 Clean Air Act Amendments, Federal Register, June 19, 1978.

The existing and proposed emissions sources in the Kuparuk Oil Field were identified with the four production facilities. The 100 drill site heaters were assumed to be distributed equally among and colocated at the four Kuparuk Oil Field production facilities. The remaining pollutant sources, existing and proposed, were also assumed to be colocated at their respective facilities. Therefore, this modeling approach is conservative.

An 8x5 receptor grid with a 0.25 km spacing was modeled around each facility for NO_x, SO_2 and PM. Pollutant sources at Prudhoe Bay were also modeled for impacts in the Kuparuk Oil Field.

<u>NO_2</u>

Annual NO_x concentrations from the Prudhoe Bay sources were predicted to exceed significance levels at receptors in the Kuparuk Oil Field. NO_x concentrations from the proposed Kuparuk Oil Field sources were also predicted to exceed significance levels in the Kuparuk Oil Field and at Prudhoe Bay. Therefore, ISCLT modeling runs were performed for all NO_x sources in the Prudhoe Bay and Kuparuk source inventories and for the 8x5 receptor grids examined in the significant impact analysis. From these runs four areas of maximum impact were identified for more refined NO_2 modeling. These "hot spots" were located around CPF and SPF in the Kuparuk Oil Field, and around Gathering Center 2 (GC-2) and Flow Station 1 (FS-1) in the Prudhoe Bay Unit. In all cases maximum impacts were predicted to occur at receptors located 0.25 km from the facilities.

<u>SO_2</u>

Annual SO_2 concentrations from the Prudhoe Bay sources did not exceed significance levels at Prudhoe Bay. The annual

SO_2 concentration from the proposed Kuparuk Oil Field sources exceed significance levels at the Kuparuk Oil Field only. Therefore, in the modeling analysis, only impacts from the Kuparuk sources on the Kuparuk Field were considered. The impact of the proposed sources exceeds 1.0 $\mu g/m^3$, the annual SO_2 significance level, and only occurs within 750 m of the CPF. Therefore, refined annual SO_2 modeling was performed only around CPF.

TSP

Annual TSP concentrations from the Prudhoe Bay sources did not exceed the annual significance level at Prudhoe Bay. Annual TSP concentrations from the proposed Kuparuk Oil Field sources were predicted to exceed the annual significance level only at the Kuparuk Oil Field. In the modeling analysis, therefore, only impacts from the Kuparuk sources on the Kuparuk Oil Field were considered. Values greater than 1.0 $\mu g/m^3$, from the proposed Kuparuk sources, were predicted to occur around all four Kuparuk Oil Field facilities, CPF, NPF, SPF, WPF. Each TSP concentration greater than the significance level was predicted to occur at 0.25 km west of each facility. These locations and values were further examined in the refined modeling. Table 6-1 shows the annual TSP screening results compared to the significance level.

6.2.2 Short Term - SO_2 and TSP

Emissions of SO_2 and PM from the proposed Kuparuk Oil Field sources were input to the ISCST model to determine areas of short-term significant impact. The model was run in its rural mode with the building wake effects option selected. A polar coordinate receptor grid was centered around the UTM coordinates for CPF and SPF. Proposed sources at each Kuparuk Oil

Field facility, including the 100 equally distributed drill site heaters were colocated at each facility. SO_2 and PM emissions were totaled for each of the facilities. The facilities were then ranked according to their total emissions. The CPF will have the greatest emissions of SO_2 and PM. The SPF, NPF, and WPF will have identical emission rates, less than the CPF. Therefore, if significance levels at SPF were exceeded it is likely that they would also be exceeded near NPF and WPF. Receptor grids were constructed around the CPF and SPF with the proposed sources colocated at the center of the grids. These receptor areas were chosen because the maximum SO_2 and PM emissions from the Kuparuk Oil Field sources will occur at these two facilities. For the screening analysis, receptors were spaced at distances of 0.25 km, 0.5 km, and 1.0 km from the origin along radials spaced 20 degrees apart.

$\underline{SO_2}$

The screening for short term impacts at CPF and SPF were examined in the ISCST model for one year of meteorological data for only the sources at the CPF. Worse-case days identified by this procedure were used in the refined modeling. A similar model run for SPF was also performed. Modeling results for the proposed Kuparuk Oil Field sources predicted 24-hour and 3-hour SO_2 concentrations will exceed the short-term significance levels at CPF only (Table 6-1). The significance levels for SO_2 will not be exceeded in the vicinity of other facilities. Therefore, refined impact analysis is necessary only for CPF.

TSP

Model predictions of 24-hour TSP concentrations show that increases due to emissions from the proposed Kuparuk Oil Field sources will exceed the significance level of 5 $\mu g/m^3$ near

CPF, NPF, SPF, and WPF. Therefore more refined modeling of 24-hour TSP impacts on the NAAQS and the PSD increments is necessary. Worse-case days identified for the CPF and SPF in the screening analysis were used in the refined modeling. The results of the short-term screening analysis are presented in Table 6-1.

6.2.3 Short-Term - CO

CO emissions were modeled in the short-term PTPLU model for each of the proposed new sources and for all stability classes (A through F). In this screening analysis the building wake effects option of PTPLU was used. The maximum concentrations predicted for each source were added together to determine a conservative total maximum 1-hour CO level for all sources. Maxima were summed without consideration given to differences in the wind speed and stability class associated with each individual maximum.

The worst-case 1-hour CO level calculated from this totalling of predicted maxima was about 757 $\mu g/m^3$ (Table 6-1). This highly conservative prediction is well below the 2000 $\mu g/m^3$ 1-hour significance level. When added to the background concentration of 171 $\mu g/m^3$ the total 1-hour CO concentration of 928 $\mu g/m^3$ falls well below the NAAQS levels of 40,000 $\mu g/m^3$ for a 1-hour period and 10,000 $\mu g/m^3$ for an 8-hour period. Therefore, no further CO analyses were warranted.

6.2.4 Short-Term - Ozone

Potential emissions of total organic compounds from the proposed Kuparuk sources will be approximately 640 tons per year. This compares to existing total hydrocarbon emissions of 1671 tons per year calculated for sources in the Prudhoe Bay area. Since the maximum 1-hour ozone levels measured in the Prudhoe Bay unit fall well below the primary and secondary NAAQS for ozone, it is highly unlikely that the small relative increase in hydrocarbon emissions from the proposed Kuparuk sources will measurably affect existing levels.

Problems associated with elevated ozone levels are commonly associated with large urban areas far away from the Kuparuk Oil Field. Ozone formation and its subsequent build-up is dependent in part on hydrocarbon/nitrogen oxides ratios, solar radiation, humidity, and temperature (Revlett, 1977). The amount of ozone formed in the photochemical process is dependent not only on the absolute concentration of hydrocarbons and nitrogen oxides, but also on the ratios. It is reasonable to assume that the concentrations of these pollutants will be proportional to their emissions. The proposed sources will emit much larger quantities of NO_x than hydrocarbons. If NO_x levels are high and hydrocarbons low, little ozone is produced (Westberg, 1978). The high levels of NO inhibit the formation of ozone over long periods of time during which the NO is oxidized to NO_2 (Hecht, 1974).

Although a precise relationship between levels of NO_x and ozone cannot be defined, quantitative estimates can be made of the relationship. One study (Miller, 1978) provides field confirmation of laboratory findings which indicate that when the hydrocarbon/NO_x ratio is less than 8/1, peak ozone levels are inversely proportional to the NO_x level. Since the increased NO_x emissions from the proposed Kuparuk Oil Field sources will be larger than the hydrocarbon emissions, by more than a factor of 20, the hydrocarbon/NO_x ratio is much less than the critical 8/1. Thus, it is not unreasonable to assume that peak ozone concentrations will decrease as the NO_x concentration increases.

A study of a large source of hydrocarbons (9000 TPY) showed a relatively small (less than 10 ppb, in plume) increase in ozone, and indicated that the emissions had a minimal effect on ambient oxidant levels (Westberg, 1978).

The extreme meteorological conditions of the Kuparuk Oil Field also inhibit ozone formation. The intensity of solar radiation is an important parameter as it governs the photolysis rate of nitrogen dioxide, the reaction that initiates and sustains the oxidant formation process. With a maximum solar angle (elevation of sun with respect to the horizon) of approximately 45°, the light intensity at the Kuparuk Oil Field is low, restricting ozone formation. The low temperatures and humidity which are common to the area also constrain the build-up of ozone.

6.3 Refined Modeling

6.3.1 Annual

NO_2

NO_x emissions from all existing, permitted, and proposed Prudhoe Bay sources and all Kuparuk Oil field existing, previously licensed, and proposed sources were examined in refined ISCLT modeling analyses to determine maximum impacts.

The ozone limiting method described by Cole and Summerhays (1979) and recommended in the 1980 draft EPA modeling guidelines was applied to determine maximum annual NO_2 levels from the predicted NO_x concentrations. Basically, this technique limits the formation of NO_2 to an in-stack conversion component and an atmospheric conversion component. The atmospheric component can not exceed the maximum predicted volumetric concentration of ozone. Maximum annual ozone concentrations were determined from existing measured annual average ozone levels using the technique discussed in the PSD Permit Application for New Sources to be Added to Existing and Previously Permitted Facilities in the Prudhoe Bay Unit (PSD IV).

The maximum annual impacts of all Kuparuk and Prudhoe Bay sources were determined from model predictions for 8 x 5 receptor grids with 0.25 km spacings constructed around CPF, NPF, SPF, and WPF. Also, a 10 x 12 grid with a 2 km receptor spacing covering the Kuparuk Oil Field was modeled for these sources. Finally, receptors near GC-2 and FS-1 were modeled to determine the NO_2 total concentrations at Prudhoe Bay.

The sources were divided into three source groups for impact determination. The first group included all proposed sources in the Kuparuk Oil Field. Group two included the Kuparuk Oil Field existing and previously licensed sources. The third source group included all the Prudhoe Bay sources as well as all sources in the first and second groups.

Predicted NO_2 concentration distributions due to emissions from proposed Kuparuk sources alone and for all Kuparuk and Prudhoe Bay sources are illustrated in Figures 6-1 and 6-2. Results of the modeling analysis are compared to the NAAQS for NO_2 in Table 6-2. Examination of Table 6-2 shows that the total NO_x emissions from all sources including the proposed Kuparuk Oil Field facilities should not result in a violation of the NAAQS for NO_2.

TSP

The screening analysis discussed in Section 6.2 identified the Kuparuk Oil Field facilities CPF, SPF, NPF, and WPF for refined modeling.

An 8 x 5 receptor grid was modeled with a 0.25 km spacing around each facility for all Kuparuk Oil Field sources. The maximum predicted TSP impacts are shown in Table 6-3. The incremental increase in maximum annual TSP concentration due to the proposed Kuparuk Oil Field sources should be only about 1.0 $\mu g/m^3$. Total PM emissions should result in concentrations well below the NAAQS and the PSD Class II increments for TSP. The results are shown in Table 6-3.

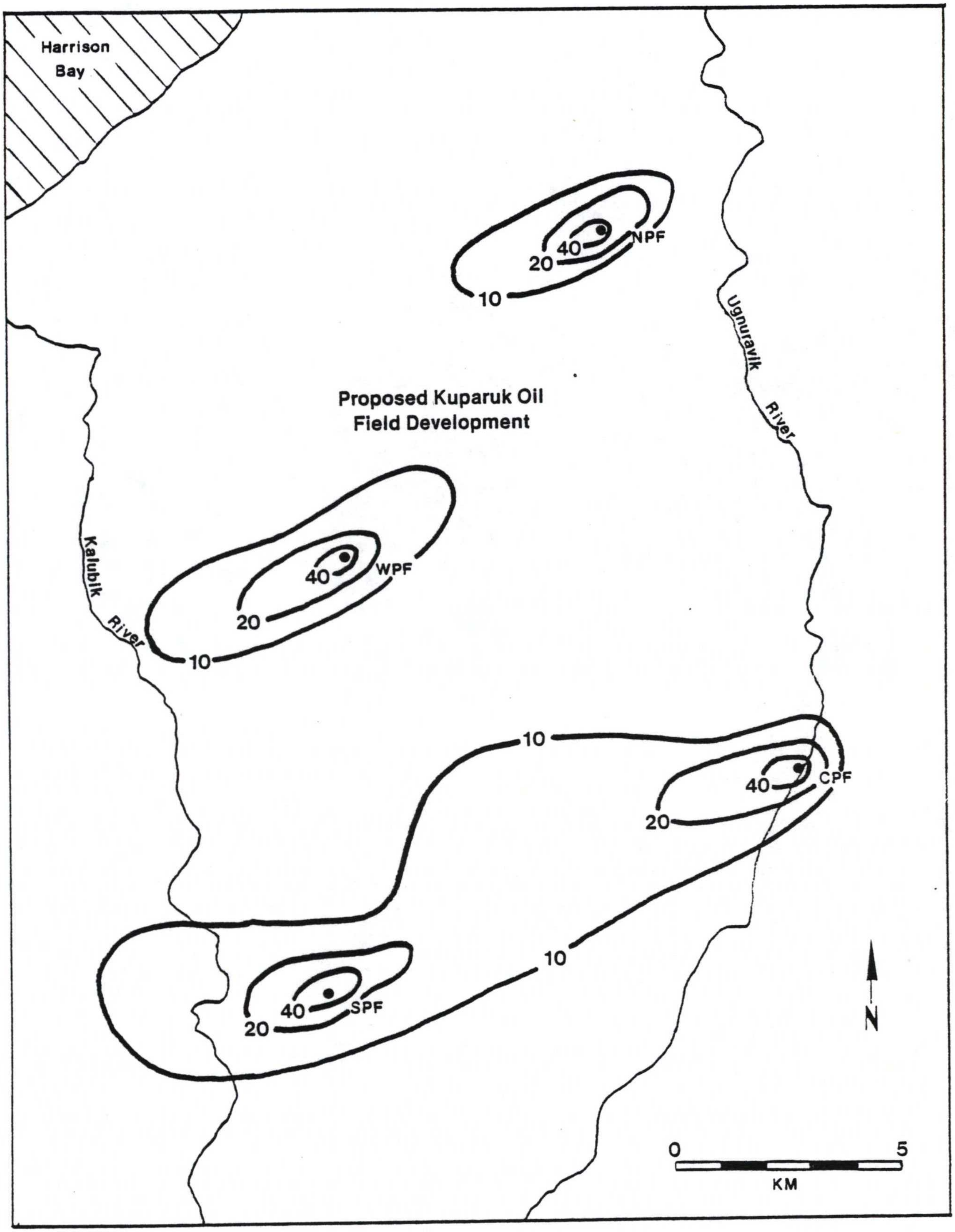


Figure 6-1. Predicted Annual NO_2 Concentrations ($\mu g/m^3$) for Proposed Kuparuk Sources Alone

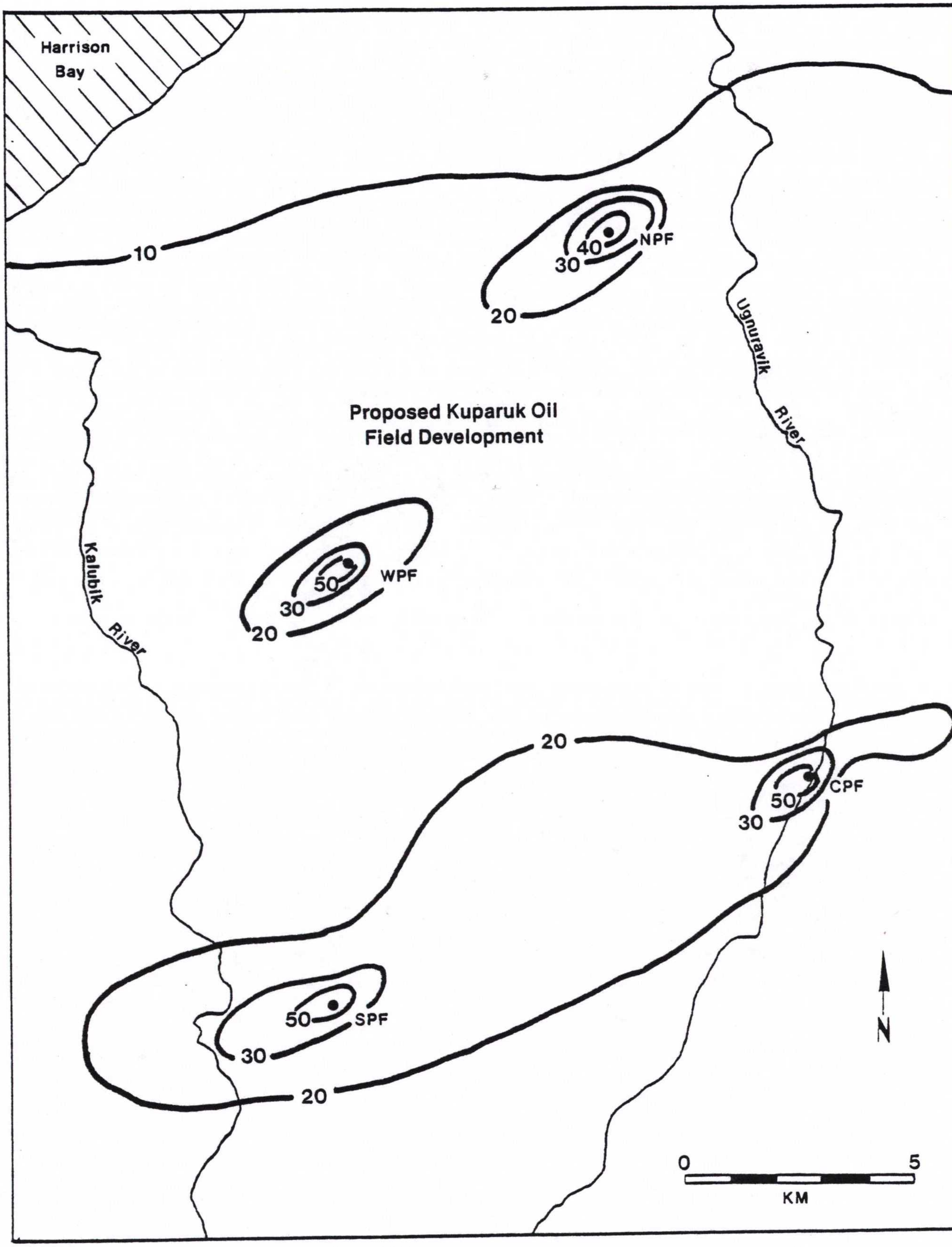


Figure 6-2. Predicted Annual NO_2 Concentrations ($\mu g/m^3$) for All Kuparuk and Prudhoe Bay Sources

TABLE 6-2

MAXIMUM PREDICTED ANNUAL NO_2 CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Receptors in the Kuparuk Area CPF Area	SPF Area	Maximum Impact Receptors in Prudhoe Bay Area
Background	2.0	2.0	2.0
Kuparuk Proposed[1]	4.1	4.4	0.14
Kuparuk Existing and[1] Previously Licensed	1.7	0.1	0.02
All Prudhoe Bay[1]	1.0	0.9	10.5
Ozone Limited NO_2[2]	49.0	49.0	49.0
TOTAL	57.8	56.4	61.7

(1) Contribution to NO_2 due to in-stack conversion (10% of total predicted NO_x concentrations).

(2) Ozone limited atmospheric NO_2 contribution as determined in PSD Permit Application for the Prudhoe Bay Unit Owners' (PSD IV), January 1981.

TABLE 6-3

MAXIMUM PREDICTED ANNUAL TSP CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Receptors in Kuparuk Area CPF Area	SPF Area*
Background	11.0	11.0
Kuparuk Proposed	1.32	1.31
Kuparuk Existing and Previously Licensed	1.49	0.04
Maximum Impact on PSD Class II Increment	2.82	1.35
Maximum Impact on NAAQS	13.82	12.35
PSD Class II Increment	19	19
Primary Annual NAAQS	75	75
Secondary Annual NAAQS	60	60

*The sources at SPF are identical to those at NPF and WPF. Maximum impacts of the proposed facilities occur at SPF because of its nearness to CPF.

SO_2

Annual SO_2 ground level concentrations from the proposed sources were identified in the screening analysis to exceed significance levels only near CPF. Therefore, revised modeling was performed around CPF for an 8 x 5 receptor grid with a 0.25 km spacing for all Kuparuk Oil Field sources. The results of this analysis are compared to the NAAQS and PSD Class II increments for SO_2 in Table 6-4. Examination of this table shows that the total SO_2 emissions from all sources, including the proposed Kuparuk Oil Field sources should not result in a violation of the NAAQS or Class II increments. The incremental increase in maximum annual SO_2 concentrations due to the proposed Kuparuk Oil Field sources alone should be only about 2.0 $\mu g/m^3$.

6.3.2 24-Hour TSP

Emissions of particulate matter from existing and proposed facilities in the Kuparuk Oil Field only were examined in a refined ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD increments. The initial screening analysis identified 24-hour periods during which TSP concentrations due to emissions from the proposed sources were predicted to exceed the significance level. Meteorological conditions associated with maximum predicted 24-hour TSP concentrations occur on Julian Day 272 and are listed in Appendix E.

In the refined analysis six by six receptor grids with 0.1 kilometer grid spacings were modeled around the areas of maximum concentrations identified for the 24-hour periods. These receptor areas are located in the vicinities of CPF, NPF, and SPF.

TABLE 6-4

MAXIMUM PREDICTED ANNUAL SO_2

CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Receptors in Kuparuk Area CPF Area
Background	*
Kuparuk Proposed	2.01
Kuparuk Existing and Previously Licensed	0.48
Maximum Impact on PSD Class II Increment	2.49
Maximum Impact on NAAQS	2.49
PSD Class II Increment	20
Primary Annual NAAQS	80

*Below detectability of instrument.

All Kuparuk Oil Field PM emissions due to existing, previously licensed, and proposed sources were examined for the worst-case days at CPF and SPF. The results of this analysis are presented in Table 6-5. This table shows that maximum predicted TSP levels fall well below the concentrations permitted by the primary and secondary NAAQS and by the PSD Class II increment.

24-Hour SO_2

Emissions of SO_2 from existing, previously licensed, and proposed facilities in the Kuparuk Oil Field were examined in a refined ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD increments. Worst-case days identified in the screening analysis were used in a refined modeling exercise. The meteorological conditions associated with the maximum predicted 24-hour SO_2 concentrations occur on Julian Day 274 and are listed in Appendix E. The modeling was performed in the same manner as the refined modeling for 24-hour TSP impacts. From analysis of screening results, however, only CPF required refined 24-hour SO_2 modeling.

The results of this analysis are presented in Table 6-6. Results show that maximum predicted 24-hour SO_2 concentrations fall below the concentrations permitted by the primary NAAQS and by the PSD Class II increment. The incremental increase due to the inclusion of the proposed Kuparuk Oil Field sources is predicted to be about 16 $\mu g/m^3$.

3-Hour SO_2

SO_2 emissions from the Kurpauk Oil Field existing, previously licensed, and proposed sources were examined in an

TABLE 6-5

MAXIMUM PREDICTED 24-HOUR

TSP CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact for CPF Area	Maximum Impact for SPF Area*
Background	11.0	11.0
Kuparuk Existing and Previously Licensed Sources	3.22	0.02
Kuparuk Proposed Sources	20.74	25.69
Impact on PSD Class II Increment	23.96	25.71
Impact on NAAQS	34.96	36.71
Allowable 24-Hour Class II Increment	37	37
Primary 24-Hour NAAQS	260	260
Secondary 24-Hour NAAQS	150	150

*Sources at SPF are identical to those proposed for NPF and WPF. However, SPF is closer to CPF, therefore, facility interaction and maximum impact is likely to occur at SPF.

TABLE 6-6

MAXIMUM PREDICTED SHORT-TERM

SO_2 CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum 24-Hour Impact Area (CPF)	Maximum 3-Hour Impact Area (CPF)
Background	*	*
Kuparuk Proposed	15.84	122.75
Kuparuk Existing and Previously Licensed	0.0	17.56
Impact on PSD Class II Increment	15.84	140.32
Impact on NAAQS	15.84	140.32
Allowable Class II Increment	91	512
Primary NAAQS	365	1300

*Below detectability of instrument.

ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD Class II increments. The initial screening analysis identified worst-case periods during which 3-hour SO_2 concentrations were predicted to exceed the significance level. Meteorological conditions associated with the maximum predicted 3-hour SO_2 concentrations occur on Julian Day 47 and are listed in Appendix E. Significance levels for 3-hour SO_2 were only exceeded around CPF. Therefore, refined modeling identical to the 24-hour SO_2 refined modeling was performed at the CPF receptor grid only.

The results of this analysis are presented in Table 6-6. Maximum predicted 3-hour SO_2 concentrations fall below the concentrations permitted by the primary NAAQS and PSD Class II increment. The incremental increase due to the Kuparuk Oil Field proposed sources alone is predicted to be about 123 $\mu g/m^3$.

6.4 References for Section 6

Bowers, J. F., J. R. Bjorklund, and C. S. Cheney, Industrial Source Complex (ISC) Dispersion Model User's Guide Vol. 1 and 2. EPA Report No. EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1979.

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Hecht, T. A., and J. H. Seinfeld, "Further Development of a Generalized Kinetic Mechanism for Photochemical Smog," Environmental Science and Technology, 8:327, 1974.

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U.S. Environmental Protection Agency, Proposed Revisions to EPA Guidelines on Air Quality Models, October 1980, Office of Air Quality Planning and Standards.

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7.0 ADDITIONAL IMPACT ANALYSES

7.1 Visibility Impacts

Particulate matter of small diameter or aerosols formed by the conversion of SO_2 and NO_x emissions to nitrates and sulfates could potentially cause some impairment to the visibility in the Kuparuk area. However, the total increase in emissions of particulate matter of all size ranges should be only about 373 tons per year as a result of the proposed new sources. In addition, maximum incremental increases in 24-hour and annual TSP concentrations should be about 20 $\mu g/m^3$ and about 1 $\mu g/m^3$, respectively. Therefore, the emissions of additional particulates should not significantly impact visibility in the area.

Enhancement of fog and ice fog formation in the study area may result from the proposed plant plumes and exhausts from the associated additional vehicles and buildings. These additional fogs and ice fogs may result in occasional incremental reductions in visibility in the Kuparuk area.

A thick haze is visible over the Arctic Ocean each spring (Kerr, 1979). Visibility aloft is often reduced from more than 100 kilometers to less than 10. The cause(s) of the Arctic haze is not certain, but long-range transport of sulfates generated from European industry is suspected. Some haze is likely to occur in the immediate Kuparuk oil field area as a result of the new facilities, but should not have a discernible effect on the widespread Arctic haze. The oil development on the North Slope was originally suspected of contributing to the Arctic haze, but is no longer considered to be a significant factor (Shaw, 1979). The haze has been reported since the 1950s, well before the oil development began. Vanadium and manganese are found in the haze particles, but are almost non-existent in fuel oils burned in Europe and the contiguous United States.

Emissions of sulfur dioxide and nitrogen oxides from the proposed sources may undergo some conversion to sulfates and nitrates. However, SO_2 emissions increases will be small and predicted increases in ambient SO_2 concentrations will fall well below the primary NAAQS. Therefore, SO_2 emissions would not significantly affect visibility in the Kuparuk area.

Incremental impacts on the frequency and severity of reduced visibility are likely to be insignificant. Furthermore, the areas of major concern with respect to visibility impairment are the PSD Class I areas. No Class I areas are located within 900 kilometers of the Kuparuk area. Therefore, no impact on visibility in Class I areas is expected.

7.2 Soils and Vegetation Impacts

Soils act as a significant sink for SO_2, NO_2, and particulates, all of which are generally removed from the air and adsorbed on the soil and plant surfaces. The rate of adsorption is dependent upon distance from the source, pollutant concentrations in the air, soil properties, density of vegetation cover, and prevailing hydrological and meteorological conditions.

The end products of soil sorption are particulate nitrates and particulate sulfates. Maximum predicted annual concentrations of NO_2 from all sources and the proposed sources alone would reach 57.8 $\mu g/m^3$ and 43.8 $\mu g/m^3$, respectively in the Kuparuk area. Increases in maximum annual and short-term concentrations for other pollutants would be insignificant or very small.

It appears that the quantities of particulate nitrates and/or sulfates, thus added to the soil and assimilated into soil-plant systems will be insignificant as compared with those normally present in these soils or transported. Thus, the amounts of pollutants added in the vicinity of the ARCO Kuparuk Oil Field should exert a negligible impact on the soils of the area.

There is currently no available information on the tolerance levels of high Arctic plants for the criteria air pollutants. The probable impacts of the proposed sources can, however, be inferred from the tolerance levels determined for plants native to lower latitudes. Table 7-1 has been taken from Heck and Brandt (1977) and indicates the threshold level for acute toxicity to plants. Comparison of the lower range for NO_2 effects on sensitive plant taxa, 3,000 $\mu g/m^3$ to the predicted total annual NO_2 levels of 57.8 $\mu g/m^3$, would indicate no acute effects could possibly be expected. Since predicted increases in ambient concentrations of other pollutants will be small, these increases should have no adverse impact on local vegetation.

Chronic effects from long-term exposure may be extremely difficult to either define or quantify. Long-term (22 days) exposure to low-levels of NO_2 (950 $\mu g/m^3$) has been reported to result in reducted productivity of a sensitive plant species (Jacobson and Hill, 1970). The levels of pollutant tested by far exceed the expected concentrations resulting from around the proposed sources. Although chronic effects due to long-term exposure to extremely low levels of NO_2 cannot be ruled out entirely; the possibility of their occurrence is remote.

TABLE 7-1

NITROGEN DIOXIDE: PROJECTED POLLUTANT CONCENTRATIONS FOR SHORT-TERM EXPOSURES THAT WILL PROVIDE ABOUT FIVE PERCENT INJURY TO VEGETATION GROWN UNDER SENSITIVE CONDITIONS[1]

	Concentrations Producing Five Percent Injury By Plant Susceptability Groupings		
Exposure Time (hours)	Sensitive Plants[2] ($\mu g/m^3$)	Intermediate Plants ($\mu g/m^3$)	Resistant Plants[3] ($\mu g/m^3$)
0.5	11,502 - 23,004	19,170 - 47,925	≥38,340
1.0	5,751 - 19,170	17,253 - 38,340	≥34,506
2.0	4,793 - 14,378	13,419 - 28,755	≥24,921
4.0	3,834 - 11,502	9,585 - 23,004	≥19,170
8.0	2,876 - 9,585	7,668 - 17,253	≥15, 336

[1]Heck and Brandt (1977)

[2]Example: nitrogen dioxide; alfalfa, barley, cotton, pine, and squash

[3]Example: nitrogen dioxide; corn, oak, cantaloupe

Thus, in general, no noticeable adverse effect is expected due to the interaction of emissions from the new sources either on soils or vegetation.

7.3 Impacts of Anticipated Induced Growth

The operation of the proposed new facilities is expected to increase the total work force in the Kuparuk area from an existing staff of approximately 400 to a staff of about 700. Increased pollutant emissions resulting from this additional work force will be limited almost entirely to those resulting from vehicle operations. However, even these emissions should be insignificant when compared with the total emissions from the proposed heaters and turbines. Consequently, the proposed new facilities are not expected to have air pollutant impacts other than those discussed in Section 6.0 of this application.

7.4 References for Section 7

Heck, W. W. and C. S. Brandt, "Effects on Biological Systems" Air Pollution, Vol. II, 3rd Edition, Edited by A. C. Stern, pp. 159-227, 1977.

Jacobson, J. S. and A. C. Hill, Recognition of Air Pollution Injury to Vegetation, Air Pollution Control Association, Pittsburgh, PA, 1970.

Kerr, Richard A., "Global Pollution: Is the Arctic Haze Actually Industrial Smog?" Science, Vol. 205, July 20, 1979, pp. 290-293.

Shaw, Glen, Personal Communications, August 1979, Geophysical Institute, University of Alaska, Fairbanks, Alaska.

APPENDIX A

KUPARUK AREA EMISSIONS INVENTORIES

Existing, Permitted, and Proposed Emissions From Other Sources

Inventories of SO_2, NO_x, and PM emissions from other existing and proposed sources were compiled for use in performing the air quality impact analyses. This appendix presents the inventories for these sources as well as the inventory for the proposed Kuparuk Oil Field additions.

The inventories were separated into the following groups:

Group 1. Prudhoe Bay Unit Owners' Existing Sources
Group 2. Prudhoe Bay PSD I Sources (Permit No. PSD-X79-05)
Group 3. Prudhoe Bay Unit Owners' PWI/LPS/AL Sources (Permit No. PSD-X80-09)
Group 4. Prudhoe Bay Unit Owners' PWI/LPS/AL Sources (Permit No. PSD-X81-01)
Group 5. Prudhoe Bay Unit Owners' Additional Sources (1980 Equipment Exchange Analysis)
Group 6. Proposed Northwest Alaska Pipeline Company Sources (1981 Northwest Alaska Pipeline Company Application)
Group 7. Prudhoe Bay Unit Owners' Proposed Additional Sources (PSD IV)
Group 8. Kuparuk Oil Field Development Existing and Previously Licensed Sources
Group 9. Kuparuk Oil Field Development Proposed Sources

The inventory for Group 1 sources is identical to that reported in the Prudhoe Bay Unit Owners' Waterflood Application. This group of sources is comprised of existing oil field sources in the Prudhoe Bay Unit and existing Deadhorse area sources.

The inventory for Group 2 is similar to that reported for sources proposed in the Prudhoe Bay Unit Owners' PSD I Application. This inventory, however, does not include sources deleted from Group 2 as a result of the Prudhoe Bay Unit Owners' 1980 Equipment Exchange Analysis.

The inventories for Groups 3 and 4 are based on the emission inventories reported in the Prudhoe Bay PWI/LPS/AL Application (1980 Permit) and Waterflood Application. These inventories, however, include all changes in assumed stack parameters covered in Case 2 of the modeling analysis reported in Radian Corporation's January 14, 1980 technical document prepared for the Prudhoe Bay Unit Owners and presented to EPA Region X. These changes are also reflected in the Prudhoe Bay Unit Owners' 1980 Equipment Exchange analysis.

The Group 5 inventory includes all additional sources reported in the Prudhoe Bay Unit Owners 1980 equipment exchange analysis.

The inventory for Group 6 consists of those sources included in the PSD permit application prepared by the R. M. Parsons Company for the Northwest Alaska Pipeline Company's proposed Gas conditioning plant.

Group 7 contains the inventory for all Kuparuk Oil Field existing and previously licensed sources.

TABLE A-1

GROUP 1: PRUDHOE BAY EXISTING SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
ACT	ARCO P-357	449.50	7794.60	.434	.009	.019	.019	.032	.006	15.2	623	1.0	10.6
ACT	ARCO P-357	449.50	7794.60	.03	.005	..003	.003	.004	..001	15.2	623	.3	10.6
ACC	ARCO P-358	448.40	7794.70	2.7	.039	.117	.117	.198	.035	15.2	623	1.0	10.6
ACT	ARCO P-136	449.30	7794.40	1.33	.00	.116	.116	.00	.17	15.2	555	1.2	10.6
ACT	ARCO P-135	449.30	7794.40	.396	.113	.038	.038	.94	.706	10.7	1033	.9	6.9
FS-1	ARCO P-138	446.10	7795.10	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-1	ARCO P-138	445.90	7795.30	2.98	.00	.025	.025	.00	..38	15.2	623	..3	10.6
FS-2	ARCO P-381	449.55	7795.60	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-2	ARCO P-381	449.45	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
FS-3	ARCO P-443	440.75	7795.80	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-3	ARCO P-443	440.75	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
AFC	ARCO P-325	443.70	7802.20	.578	.00	.50	.50	.00	.076	16.1	611	.9	10.6
AFC	ARCO P-324	443.70	7802.20	164.0	2.12	5.58	5.58	45.70	16.7	25.8	755	2.4	50.6
AFC	ARCO P-324	443.70	7802.20	1.53	.022	.066	.066	.113	.02	9.1	519	1.1	10.6
CC-1	SOHIO P-338	435.80	7799.50	.037	.063	.176	.095	.25	.076	7.3	1088	.5	6.9
CC-1	SOHIO P-338	435.80	7799.50	.13	.064	.16	.086	.009	.032	7.3	1088	.5	7.4
CPS	SOHIO P-185	437.50	7797.20	109.2	1.403	3.70	3.70	30.30	11.4	15.8	777	2.7	50.6
CPS	SOHIO P-183	437.50	7797.20	20.31	.258	.69	.69	5.63	2.12	15.8	777	2.7	50.6
DW	DOW P-325	447.90	7792.00	1.25	.059	.044	.044	.767	.125	3.7	721	.2	15.2
DW	DOW P-325	447.90	7792.00	.078	.16	.067	.067	.006	.004	3.7	721	.2	7.4
N1	NANA P-413	447.30	7791.00	.76	.63	.011	.011	8.82	.377	20.0	450	.9	13.7
N1	NANA P-413	447.30	7791.00	.38	.32	.006	.006	4.41	.189	20.0	450	.9	7.4
PS1	ALY. P-289	439.00	7796.00	25.1	.320	.85	.85	6.99	2.55	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.04	.009	.035	.035	.289	.105	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.56	.022	.067	.067	.115	.02	13.7	623	1.0	10.7
PS1	ALY. P-289	439.00	7796.00	.00	.014	.001	.001	.00	.00	7.9	1144	.4	6.9
PS1	ALY. P-289	439.00	7796.00	.062	.01	.003	.003	.001	.002	7.9	1144	.4	7.4
N2	NANA P-423	444.40	7789.40	9.66	.64	.69	.69	2.09	.77	7.6	431	.5	18.3
N2	NANA P-434	444.40	7789.40	.04	.113	.707	.707	.904	.706	10.7	1032	.9	6.9
VE	VE P-482	446.00	7791.60	7.00	.47	.50	.39	1.51	.56	7.6	421	.5	15.2
VE	VE P-482	446.00	7791.60	.195	.055	.35	.35	.47	.35	10.6	1033	.9	6.9
AOC	ARCO OPS CR	449.80	7794.60	.26	.431	.047	.035	.153	.397	12.2	971	1.1	6.9
AOC	ARCO OPS CR	449.80	7794.60	.08	.038	.018	.014	.01	.043	12.2	1366	.8	7.4
SOC	SOHIO BOC	435.80	7799.50	.063	.034	.02	.02	.007	.008	12.2	1366	.5	6.9
SOC	SOHIO BOC	435.80	7799.50	.003	.052	.002	.00	.13	.404	12.2	1088	.5	7.4
SOC	SOHIO BOC	435.80	7799.50	.20	.53	.40	.009	6.91	1.14	6.7	660	.5	18.3

TABLE A-1 (Continued)

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
CC-2	SOHIO P-374	430.00	7803.50	.03	.047	.066	.066	.187	.056	12.2	1088	.5	6.9
CC-2	SOHIO P-347	430.00	7803.50	.106	.054	.041	.041	.009	.022	12.2	1088	.5	7.4
	DH. ARPRT	445.00	7789.00	15.67	1.14	1.12	1.12	3.38	1.25	10.7	428	.6	22.8
FC	FRONTIER	445.70	7791.20	7.83	.52	.56	.56	1.69	.63	10.7	428	.5	18.3
	ACC	427.00	7801.80	2.61	.17	.19	.19	.56	.21	10.7	428	.3	18.3
FC	Downtown	446.50	7791.20	13.06	.87	.93	.93	2.82	1.04	10.7	428	.6	15.2
CC-1	SOHIO GC1	434.75	7800.90	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-1	SOHIO GC1	434.60	7800.95	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CC-2	SOHIO GC2	429.95	7801.90	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-2	SOHIO GC2	430.05	7801.90	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CC-3	SOHIO GC3	436.65	7798.60	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-3	SOHIO GC3	436.60	7798.55	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CPS	SOHIO CPS	437.50	7797.20	.28	.005	.012	.012	.02	.004	18.0	506	.4	3.5

<u>TABLE A-2</u>

<u>GROUP 2: PRUDHOE BAY UNIT OWNERS' PSD 1 SOURCES</u>

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SOHIO GC2	430.10	7801.85	35.33	.295	1.20	1.20	9.00	3.58	16.7	470	1.71	60.0
SOHIO GC3	436.70	7798.50	8.80	.077	.30	.30	2.45	.90	16.7	755	2.69	35.0
SOHIO CPS	437.50	7797.20	35.90	.304	1.25	1.25	10.31	3.77	16.7	755	2.80	42.0

TABLE A-3

GROUP 3: PRUDHOE BAY UNIT OWNERS' PWI/LPS/AL SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
GC-1	434.70	7800.90	5.20	.032	.115	.115	.95	.17	16.7	830	.88	50.0
GC-1	434.75	7801.00	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-1	434.65	7801.10	67.20	.410	1.67	1.67	12.54	2.27	16.7	470	1.71	50.0
GC-1	434.75	7801.10	2.04	.039	.115	.115	.20	.03	7.6	623	.94	10.6
GC-1	434.60	7801.05	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-1	434.65	7800.90	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.85	5.20	.032	.115	.115	.95	.17	16.7	830	.88	50.0
GC-2	430.00	7801.85	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-2	430.05	7801.80	126.52	.773	3.17	3.17	23.58	4.28	16.7	470	1.71	50.0
GC-2	429.95	7801.80	3.05	.058	.17	.17	.29	.05	7.6	623	.94	10.6
GC-2	430.00	7801.75	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.75	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.70	7798.45	5.20	.032	.12	.12	.95	.17	16.7	830	.88	50.0
GC-3	436.65	7798.50	1.04	.006	.03	.03	.20	.03	16.7	830	.55	50.0
GC-3	436.80	7798.45	67.20	.410	1.67	1.67	12.54	2.27	16.7	470	1.71	50.0
GC-3	436.60	7798.45	2.01	.039	.115	.115	.20	.07	7.6	623	.94	10.6
GC-3	436.70	7798.40	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.75	7798.60	7.39	.142	.42	.42	.72	.127	7.6	623	.73	10.6
DRILL PAD E	437.10	7804.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD F	433.50	7804.40	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD G	435.00	7802.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD D	434.90	7799.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD H	430.90	7800.10	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD J	430.80	7803.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD M	426.40	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD N	428.10	7802.50	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD R	428.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Q	431.00	7801.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD S	423.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Y	431.20	7796.80	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3

TABLE A-3 (Continued)

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
DRILL PAD A	434.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD C	437.30	7799.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD X	437.00	7793.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD B	437.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
CCP	443.70	7802.20	18.58	.113	.46	.46	3.45	.63	16.7	470	1.71	50.0
CCP	443.70	7802.20	.63	.012	.03	.03	.06	.01	9.1	519	.5	14.1
FS-1	446.00	7795.25	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-1	446.00	7795.20	80.29	.490	1.84	1.84	14.96	2.73	16.7	470	1.71	50.0
FS-2	449.55	7795.50	107.05	.654	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-2	449.55	7795.40	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-2	449.45	7795.50	2.39	.046	.14	.14	.23	.04	15.0	530	.9	12.0
FS-3	440.75	7795.70	107.05	.654	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-3	440.65	7795.80	7.45	.045	.18	.18	1.40	.25	16.8	748	1.0	29.7

TABLE A-4

GROUP 4: PRUDHOE BAY UNIT OWNERS' WATERFLOOD SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
SWT	SWTR TRT	443.00	7810.10	7.88	.151	.45	.45	.78	.14	28.0	530	1.4	12.0
SWT	SWTR TRT	443.00	7810.10	2.85	.055	.16	.16	.28	.05	28.0	530	1.0	12.0
IPE	E INJ PLT	445.50	7795.00	59.47	.363	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	435.00	7800.70	59.47	.363	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	435.00	7800.70	2.39	.046	.14	.14	.23	.04	15.0	530	.9	12.0
IPE	E INJ PLT	445.50	7795.00	2.39	.046	.14	.14	.23	.04	18.3	530	.9	12.0

TABLE A-5

GROUP 5: PRUDHOE BAY UNIT OWNERS' ADDITIONAL SOURCES EQUIPMENT EXCHANGE ANALYSIS

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SIPW	435.00	7800.70	11.9	.073	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPW	435.00	7800.70	18.0	.342	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
GC-2	429.95	7801.70	5.6	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.70	7798.55	5.6	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
STP	443.00	7810.10	7.2	.137	.41	.41	.68	.12	22.2	450	0.91	14.4
SIPE	445.50	7795.00	11.9	.073	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPE	445.50	7795.00	18.0	.342	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
SIPE	445.50	7795.00	18.6	.114	.45	.45	3.47	.63	22.2	450	1.77	29.9

TABLE A-6

GROUP 6: NORTHWEST ALASKAN PIPELINE COMPANY PROPOSED SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
AGCF	443.13	7802.39	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.17	7802.20	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.12	7802.40	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.16	7802.21	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.30	7802.33	96.31	1.90	1.85	1.85	23.10	4.20	28.96	605.2	3.81	15.24
AGCF	443.38	7802.05	128.64	2.52	2.52	2.52	30.96	5.64	28.96	605.2	4.02	15.24
AGCF	443.31	7802.15	42.88	.84	.84	.84	10.32	1.88	28.96	605.2	4.02	15.24
AGCF	443.31	7802.11	16.47	.32	.32	.32	3.76	.66	28.96	781.3	2.84	15.24
AGCF	443.07	7802.24	79.29	1.56	1.53	1.53	19.08	3.48	28.96	605.2	4.47	15.24
AGCF	443.23	7801.97	3.51	.99	.45	.45	.48	.09	38.10	421.9	1.16	15.24
AGCF	443.22	7801.97	7.44	2.07	.93	.93	1.05	.19	38.10	449.7	1.74	15.24
AGCF	443.33	7802.21	6.51	1.83	.81	.81	.93	.17	38.10	421.9	1.58	15.24
AGCF	441.50	7802.40	.30	.012	.01	.01	.011	.002	28.96	421.9	0.53	15.24
AGCF	441.60	7802.30	.35	.05	.05	.05	.00	.00	28.96	421.9	0.15	3.05
AGCF	441.60	7802.40	1.42	.016	.05	.05	.58	.107	28.96	605.7	0.86	15.24
AGCF	439.50	7796.80	.16	.05	.05	.05	1.14	.20	28.96	605.7	0.49	15.24

TABLE A-7

GROUP 7: PRUDHOE BAY UNIT OWNERS' PROPOSED ADDITIONAL SOURCES

	UTM (km)		NO_x		Particulate							
			Annual		Short Term	Annual						
Map ID	East	North	(g/s)	SO_2 (g/s)	(g/s)	(g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
GC-1	434.70	7800.95	11.53	.068	.28	.28	2.08	.38	22.2	450	1.16	31.4
GC-1	434.65	7801.00	26.90	.159	.66	.66	4.85	.88	22.2	450	1.98	33.2
GC-2	430.05	7801.70	17.29	.102	.43	.43	3.12	.57	22.2	450	1.16	31.4
GC-2	430.10	7801.75	34.59	.204	.85	.85	6.24	1.13	22.2	450	1.98	33.2
GC-3	436.75	7798.50	5.76	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.80	7798.55	46.12	.272	1.13	1.13	8.32	1.51	22.2	450	1.98	33.2
IPW	435.00	7800.70	19.22	.113	.47	.47	3.47	.63	22.2	450	1.98	33.2
FS-1	446.00	7795.15	3.84	.023	.09	.09	.69	.13	22.2	450	1.16	31.4
FS-1	445.90	7795.10	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
FS-1	446.10	7795.30	27.67	.163	.68	.68	4.99	.91	22.2	450	1.98	33.2
FS-2	449.45	7795.40	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.70	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.60	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
SWT	443.00	7810.10	24.60	.145	.60	.60	4.44	.81	22.2	450	.76	29.0

TABLE A-8

GROUP 8: KUPARUK OIL FIELD DEVELOPMENT EXISTING AND PREVIOUSLY LICENSED SOURCES

Map ID	Description	UTM (km) East	UTM (km) North	NO_x g/s	SO_2 g/s	PM g/s	CO g/s	HC g/s	HS (m)	TS (°K)	DS (m)	VS (m/s)
CPF	4-5 MHP turbines w/WHR	401.25	7804.24	13.6	0.08	0.28	2.72	0.48	18.4	475	1.2	29.9
CPF	2-14 MHP turbines w/WHR	401.25	7804.24	19.4	0.1	0.42	3.88	0.70	24.4	500	2.2	22.4
CPF	5-10 MMBtu/hr heaters	401.24	7804.25	1.3	0.02	0.085	0.094	0.015	17.4	450	0.8	8.6
CPF	1-20 MMBtu/hr heater	401.24	7804.25	0.53	0.008	0.034	0.039	0.007	26.2	450	0.9	6.0
CPF	1-1300 lb/hr incinerator	401.24	7804.25	0.25	0.2	0.58	0.82	0.025	12.3	1144	1.2	12.4

TABLE A-9

GROUP 9: KUPARUK OIL FIELD DEVELOPMENT PROPOSED SOURCES

Map ID	UTM (km) East	North	NO_x g/s	SO_2 g/s	PM g/s	CO g/s	HC g/s	HS (m)	TS (°K)	DS (m)	VS (m/s)
CPF	401.25	7804.25	1.05	0.015	0.069	0.078	0.014	26.2	450	0.9	6.0
	401.25	7804.25	29.1	0.15	0.63	5.8	1.05	24.4	500	2.2	22.4
	401.25	7804.25	188.1	0.96	4.09	37.68	6.89	24.4	500	2.2	43.9
	401.25	7804.25	5.5	0.08	0.36	0.40	0.06	17.4	450	0.8	8.2
	401.25	7804.25	0.32	0.24	0.02	1.59	3.2	18.3	1000	0.05	52.13
NPF	397.00	7815.75	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	397.00	7815.75	38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	397.00	7815.75	6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	397.00	7815.75	0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7
SPF	391.25	7799.25	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	391.25	7799.25	38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	391.25	7799.25	6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	391.25	7799.25	0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7
WPF	391.50	7808.75	27.19	0.16	0.55	5.4	0.96	18.3	475	1.2	29.9
	391.50	7808.75	38.79	0.20	0.84	7.76	1.40	24.4	500	2.2	22.4
	391.50	7808.75	6.49	0.10	0.43	0.47	0.08	17.4	450	0.8	8.2
	391.50	7808.75	0.53	0.01	0.04	0.04	0.01	26.2	450	0.9	5.7

APPENDIX B

EMISSIONS CALCULATIONS

APPENDIX B - EMISSIONS CALCULATIONS

Fuel Composition supplied by Arco:

Component	Molecular Weight	Mole %
CO_2	44.1	1.3
N_2	28.016	0.7
CH_4	16.043	78.0
C_2H_6	30.070	10.0
C_3H_8	44.097	10.0
H_2S	34.00	0.002 (20 ppm) negligible

Heating Value of Fuel = 1100 Btu/scf @ 25°C, 1 atm (supplied by Arco)

$$PV = nRt$$

$$V = \frac{nRT}{P}$$

$$V = \frac{(\text{lb mole})(1.31 \text{ atm ft}^3/\text{lb mole°K})(298.2\text{°K})}{1 \text{ atm}}$$

$$V = 390.6 \text{ scf/lb mole fuel @ } 298.2\text{°K, 1 atm}$$

0.78	1.56	0.78	1.56	(moles)
CH_4 +	$2O_2$	CO_2 +	$2H_2O$	
0.1	0.35	0.2	0.3	
C_2H_6 +	$3.5O_2$	$2CO_2$ +	$3H_2O$	
0.1	0.5	0.3	0.4	
C_3H_8 +	$5O_2$	$3CO_2$ +	$4H_2O$	
0.98	2.41	1.28	2.26	(mole totals)

O_2 needed = 2.41 moles/mole fuel

$N_2 = \frac{79}{21} \times 2.41 = 9.07$ moles/moles fuel

CO_2 formed = 1.28 moles/moles fuel

H_2O formed = 2.26 moles/moles fuel

So with complete combustion at 0% excess O_2, the flue gas produces are:

Component	mole/mole fuel	Stoichiometric flue gas, moles
CO_2	0.013 + 1.28	1.29
N_2	0.007 + 9.07	9.08
H_2O	2.26	2.26

With complete combustion with 15% excess O_2 in flue gas, the total lb moles O_2 (dry) per lb mole of fuel, X is calculated by the following equation.

$$0.15 = \frac{X \text{ lb mole } O_2}{X \text{ moles } O_2 + 1.29 \text{ lb moles } CO_2 + 9.08 + \frac{79}{21} \text{ lb moles } NO_2}$$

$$0.15 = \frac{X}{4.7619X + 10.36}$$

$$X = 0.15\ (4.7619X + 10.36)$$

$$X = 0.7143X + 1.554$$

$$1X - 0.7143X = 1.554$$

$$0.2857X = 1.554$$

$X = 5.4389$ lb moles O_2/lb moles fuel

Therefore, the flue gas products dry are:

Component	lb moles flue gas/lb moles fuel
CO_2	1.29*
N_2 : $\left(\frac{79}{21} \times 5.4389\right) + 9.08$	29.54
O_2	5.44
	36.27 lb moles flue gas/lb moles fuel

*ignore 0.03% CO_2 in air

NO_x Emissions from Gas Turbines

NO_x flue gas concentration = 150 ppmv in flue gas on a dry basis at 15% excess O_2

9433 Btu/hp-hr = maximum heat rate for turbines in this permit

Dry

$$\frac{\text{lb moles flue gas}}{\text{hp-hr}} = \frac{9433\ \text{Btu}}{\text{hp-hr}} \times \frac{\text{lb moles fuel}}{390.6\ \text{scf fuel}}$$

$$\times \frac{36.3\ \text{moles flue gas}}{\text{lb mole fuel}} \times \frac{\text{scf fuel}}{1100\ \text{Btu}}$$

$$= \frac{0.7969\ \text{lb moles flue gas}}{\text{hp-hr}}$$

$$\frac{\text{lb}}{1000\ \text{hp-hr}} = \frac{0.7969\ \text{lb moles flue gas}}{\text{hp-hr}} \times \frac{0.000150\ \text{lb moles } NO_2}{\text{lb mole flue gas}}$$

$$\times \frac{46.008\ \text{lb } NO_2}{\text{lb mole}} \times 1000$$

$$= 5.5\ \text{lbs } NO_x/1000\ \text{hp-hr}$$

HC Emissions* from Gas Turbines

Emission factor = 0.2 $\frac{\text{lb HC}}{\text{1000 hp-hr}}$ from AP-42 Table 3.3.2-1

Proposed Turbine hp = 14 MHP

HC Emissions = 14,000 hp x $\frac{\text{0.2 lb HC}}{\text{1000 hp-hr}}$ x $\frac{\text{8760 hr}}{\text{yr}}$

x $\frac{\text{ton}}{\text{2000 lb}}$

= 12.3 $\frac{\text{tons HC}}{\text{yr}}$

Proposed Turbine, hp	Tons HC/yr
14,000	12.3

*Expressed as total HC.

CO Emissions from Gas Turbines

Emission factor = $\frac{\text{1.1 lb CO}}{\text{1000 hp-hr}}$ from AP-42 Table 3.3.2-1

CO Emissions = 14,000 hp x 1.1 $\frac{\text{lb C}}{\text{1000 hp-hr}}$ x $\frac{\text{8760 hr}}{\text{yr}}$

x $\frac{\text{ton}}{\text{2000 lb}}$

= 67.5 ton CO/yr

Proposed Turbine, hp	tons CO/yr
14,000	67.5

Particulate Emissions from Gas Turbines

Emission factor = 14 lb/10^6 ft^3 gas burned, from AP-42, Table 3.3.1-2

$$\text{Particulate matter Emissions} = \frac{14 \text{ lbs PM}}{10^6 \text{ scf}} \times \frac{\text{scf}}{1100 \text{ Btu}} \times \frac{9433 \text{ Btu}}{\text{hp-hr}}$$

$$\times 1000$$

$$= 0.12 \text{ lb PM/1000 hp-hr}$$

Proposed Turbine, hp	tons PM/yr
14,000	7.4

SO_2 Emissions from Gas Turbines

Emissions Assumptions

1. H_2S content of fuel gas = 20 ppm
2. $H_2S + 3/2\ O_2 \rightarrow SO_2 + H_2O$
3. 1 mole H_2S = 1 mole SO_2
4. SO_2 = 20 ppm in fuel
5. Turbine standard heat rate = 9433 Btu/hp-hr
6. Standard Cond. = 25°C, 298.2°K, 1 atm

$$\text{Emission factor} = \frac{20 \text{ lb moles } H_2S}{10^6 \text{ lb mole fuel}} \times \frac{\text{lb mole } SO_2}{\text{lb mole } H_2S}$$

$$\times \frac{64 \text{ lb } SO_2}{\text{lb mole } SO_2} \times \frac{\text{lb mole fuel}}{390.6 \text{ scf fuel}}$$

$$\times \frac{\text{scf fuel}}{1100 \text{ Btu}} \times \frac{9433 \text{ Btu}}{\text{hp-hr}} \times 1000$$

$$= 0.028 \text{ lb } SO_2\text{/1000 hp-hr}$$

Gas Turbine Stack Parameters

Assume 5 MHP turbine parameters from Sohio Increment IV PSD Application.

$$\frac{475}{450}(1.16^2 \times 31.4) = 44.6$$

Find new diameter, assume

$$V_s = 31.4 \text{ m/s}$$

$$D^2(31.4) = 44.6 \qquad D = 1.2\text{m}$$

Find new V_s

$$Q = D^2 V_s$$

$$V_{s(new)} = \frac{44.6}{(1.2)^2}$$

$$V_{s(new)} = 29.9 \text{ m/s.}$$

For 14 MHP turbines with WHR

Exit temperature - 440°F = 500°K

Turbine flow from NW Alaska Pipeline Application, page 99.

$$\frac{T_2}{T_1} \times D^2 V_s = (D^2 V_s) \text{ new}$$

$T_1 = 609.7°K$
$T_2 = 500°K$
$D = 2.89$ m
$V_s = 15.24$ m/s

$$\frac{500}{609.7} \times (2.89)^2 (15.24) = 104.38$$

Find new velocity, assume

$D = 2.2$ m

$104.38 = (2.2)^2 V_s$ $\qquad V_s = 22.4$

For 34 MHP turbines with WHR

Exit temperature = 440°F = 500°K.

Turbine parameters based on turbine stack parameter comparison by Stanley W. Hungerford, Alaska Dept. of Environmental Conservation, January 19, 1980.

$$\frac{T_2}{T_1} \times D^2 V_s = (D^2 V_s) \text{ new}$$

$D = 2.8$ m
$V_s = 42.0$ m/s
$T_1 = 755°K$

Find new diameter, assume

$V_s = 42.0$ m/s

$D^2 (42.0) = 218.1$ $\qquad D = 2.2$ m

Emissions from Gas Heaters

The potential emissions of pollutants from gas heaters were calculated using the following equation:

$$\text{Emission Rate (tons/yr)} = \text{Heat rate of heater} \times \frac{\text{scf}}{1100\ \text{Btu}} \times \frac{8760\ \text{hr}}{\text{yr}} \times \text{EF*} \times \frac{\text{ton}}{2000\ \text{lb}}$$

Emission factors were taken from Table 1.4-1 of AP-42.

PM = 15 lb/10^6 ft^3 highest of 5-15 range given
CO = 17 lb/10^6 ft^3
HC (as CH_4) = 3 lb/10^6 ft^3
NO_x (as NO_2) = 230 lb/10^6 ft^3 highest of 120-230

*EF = Emission factor $\left(\frac{\text{lbs pollutant}}{10^6\ \text{ft}^3\ \text{burned}}\right)$

SO_2 Emission Factor for Gas Heaters

Emission Assumptions:

1. H_2S in fuel = 20 ppm
2. $H_2S + 3/2\ O_2 \rightarrow SO_2 + H_2O$
3. 1 mole H_2S = 1 mole SO_2
4. SO_2 + 20 ppm
5. Heater = 10 MMBtu/hr
6. Standard Conditions = 25°C, 1 atm

$$SO_2 \text{ Emission Factor for Heaters} = \frac{20 \text{ lb moles } H_2S}{10^6 \text{ lb moles fuel}} \times \frac{\text{lb mole } SO_2}{\text{lb mole } H_2S}$$

$$\times\ 64 \frac{\text{lb } SO_2}{\text{lb mole } SO_2} \times \frac{\text{lb mole fuel}}{390.6 \text{ scf}}$$

$$= 3.3 \frac{\text{lb } SO_2}{10^6 \text{ scf fuel}}$$

SO_2 Emissions from 10 MMBtu/hr Heater

$$\text{Heater } SO_2 \text{ Emissions} = 3.3 \frac{\text{lb } SO_2}{10^6 \text{ scf}} \times \frac{10 \text{ MMBtu}}{\text{hr}} \times \frac{\text{scf}}{1100 \text{ Btu}}$$

$$\times \frac{8760 \text{ hr}}{\text{yr}} \times \frac{\text{ton}}{2000 \text{ lbs}}$$

$$= 0.13 \text{ tons } SO_2/\text{yr}$$

Emissions Summary for Heaters

Proposed Heater 10^6 Btu/hr	Pollutant	EF $lb/10^6\ ft^3$	Emissions Rate tons/yr
10	PM	15	0.60
10	CO	17	0.68
10	HC (total)	3	0.12
10	NO_x	230	9.16
10	SO_2		0.13

Incinerator

1300 lb/hr combined waste incinerator-assume 10% moisture

Dry combustibles = 1300 lb/hr x .9 = 1170 lb/hr

Moisture total = 1300 lb/hr x .1 = $\underline{130 \text{ lb/hr}}$

1300 lb/hr

Gross heat input = 8820 Btu/lb garbage from AP-40, page 446.

1170 lb/hr x 8820 Btu/lb = 10.3 MMBtu/hr

Assume 20% heat losses due to radiation, convection, and storage heat.

$0.2 \times 10.3 \times 10^6$ MMBtu/hr = 2.1 MMBtu/hr

Evaporation of contained moisture, heat of vaporization of water at 60°F is 1060 Btu/lb from AP-40, page 946.

130 lb H_2O/hr x 1060 Btu/lb = 0.14 MMBtu/hr

Evaporation of water formed by combustion.

$$0.56 \frac{\text{lb } H_2O}{\text{lb garbage}}$$ from AP-40, page 446

$$1170 \frac{\text{lb garbage}}{\text{hr}} \times 0.56 \frac{\text{lb } H_2O}{\text{lb garbage}} \times 1060 \frac{\text{Btu}}{\text{lb}}$$

$$= 0.69 \frac{\text{MMBTU}}{\text{hr}}$$

Total heat losses.

$2.1 + 0.14 + 0.69 = 2.93$ MMBtu/hr

Net heat available.

$10.3 - 2.93 = 7.4$ MMBtu/hr

Weight of productions of combustion

200% excess air = $\frac{20.58 \text{ lb products}}{\text{lb garbage}}$ from AP-40, page 466.

Garbage (1170 lb/hr)(20.58 lb prod/lb) =	24,100 lb/hr
Moisture 130 lb/hr	+ 130 lb/hr
	24,230 lb/hr

Average gas temperature at 200% excess air.

$$Q = Wp\ Cp\ (T_2 - T_1)$$

where Q = net available heat

Wp = flow rate of combustion products, lb/hr

Cp = specific heat of products of combustion, Btu/lb-°F*

T_2 = average gas temperature, °F

T_1 = initial temperature, °F

$$T_2 = T_1 + \frac{Q}{Wp\ Cp} = 60°F + \frac{7.4 \times 10^6 \text{ Btu/hr}}{24{,}230 \text{ lb/hr} \times 0.26 \text{ Btu/lb-°F}}$$

$$T_2 = 1344°F$$

*from <u>Steam</u>, page 11-24

Volume of Combustion Products

Volume through flame port with 200% x's air
267.72 scf/lb   AP-40, page 466

$$\text{Garbage} \quad 1170 \text{ lb/hr} \times 267.7 \text{ scf/lb} = 3.13 \times 10^5 \text{ scf/hr}$$

$$\text{Moisture} \quad 130 \text{ lb/hr} \times \frac{379 \text{ scf/hr}}{18 \text{ lb/mole}} = \underline{2.73 \times 10^3 \text{ scf/hr}}$$

$$3.16 \times 10^5 \text{ scf/hr}$$

Volume through mix chamber

Assume 50% theoretical air added

$$1170 \text{ lb/hr} \times 85.12 \text{ scf/lb} \times 0.5) = 49{,}795 \text{ scf/hr}$$

$$\text{Total} = (3.16 \times 10^5 + 49{,}795) \text{ scf/hr} = 3.65 \times 10^5 \text{ scf/hr}$$

$$3.65 \times 10^5 \frac{\text{scf}}{\text{hr}} \times \frac{\text{hr}}{60 \text{ min}} \times \frac{\text{min}}{60\text{s}} = 102 \frac{\text{scf}}{\text{s}}$$

Stack Area

Assume 30 fps velocity from AP-40, page 442

NANA data from Prudhoe Bay LPS/WPI Application.

$$\text{area} = \frac{(Q)(T_2)}{(V)(T_1)} = \frac{(102 \text{ scf/s})(1804°\text{R})}{(30 \text{ fps})(520°\text{R})}$$

$$= 11.8 \text{ ft}^2$$

Stack Diameter

$$A = \frac{\pi D^2}{4} \quad D = \sqrt{\frac{(4)\ 11.8 \text{ ft}^2}{\pi}} = 4.0 \text{ ft}$$

$$= 1.2 \text{ m}$$

Crude Oil Topping Unit Stack Parameters

Crude oil topping unit exit velocity is 1/5 sonic velocity before combustion.

$$v = \frac{1}{5}\sqrt{\frac{gKRT}{M}}$$

$g = 32.17$ lbm ft/lbf sec^2

$k = Cp/Cv \sim 1.2$

$R = 154.6$ ft lbf/°R

$T =$ fuel temp., temp °R = 150°F + 460 = 610 °R

$M =$ molecular wt = 49.4 lb/lb mole

$$v = \frac{1}{5}\sqrt{\frac{(32.17)(1.2)(610)(1546)}{49.4}} = 171 \text{ ft/sec} = 52.13 \text{ m/s}$$

$$250{,}000 \ \frac{SCF}{Day} \ \frac{Day}{1440 \times 60 \ sec} \ \frac{610}{520} = 2.9 \ in^2 = \frac{\pi d^2}{4}$$

$d = 1.9$ in.
$= 0.05$ m

Emissions Calculations for Crude Oil Topping Unit Overhead Vapors Being Flared

Data

250,000 SCF/D crude tower oil gas is flared

40 x 10^6 Btu/hr crude furnace duty (design)

Exit temperature is assumed to be 1000°K.

COT flare is 60' above grade.

January 7, 1976, Oil & Gas Journal lists North Slope crude as 26.8°API (312.6 #/BBL), 1.04 wt % sulfur, 2.9 RVP, -5°F poor point.

Distillate - 0.20 wt %S	Light gas oil - 0.90 wt %S
Diesel - 0.56 wt %S	Residual - 1.74 wt %S

Crude oil topping unit oil composition assumed from a typical U.S. refinery analysis of low sulfur domestic crude.

	Mole %	MW	LHV Btu/SCF
C_1	6.5	16.0	911
C_2	13.3	30.1	1631
C_3	32.8	44.1	2374
C_4	27.7	58.1	3100
C_5	9.8	72.2	3700
C_6	6.5	86	4400
CO_2	0.9	44.0	--
N_2	2.5	28.0	--
	100.0	59.5	2562

$$\left(250{,}000\ \frac{\text{SCF}}{\text{D}}\right)\left(\frac{\text{D}}{24\ \text{hr}}\right)\left(\frac{2562\ \text{Btu}}{\text{SCF}}\right)$$

$$= 27 \times 10^6\ \text{Btu/hr}$$

The U.S. refinery crude oil analysis showed 0.13 wt % of the inlet crude oil sulfur emitted in the crude oil gas. The crude oil gas was approximately 240 ppm H_2S (this number is largely a function of amount of free H_2S in crude).

Emissions Calculations

There are no estimates available for emissions from flares, therefore AP-42 Table 1.4-1 factors were used, except where a conservative approach would indicate otherwise.

Assume the oil gas composition is same for the COT as for the U.S. refinery for which data are available.

The H_2S concentration is then;

$$\left(\frac{1.04 \text{ wt \% S in N. Slope crude}}{0.234 \text{ wt \% S in U.S. refinery}}\right)\left(\begin{matrix}240 \text{ ppm } H_2S \text{ in} \\ \text{U.S. refinery}\end{matrix}\right) = 1067 \text{ ppm}$$

Particulates

15 $\#/10^6$ ft^3 from AP-42

$$\left(\frac{15 \#}{10^6 \text{ ft}^3}\right)\left(250{,}000 \ \frac{\text{SCF}}{\text{day}}\right)\left(\frac{365 \text{ D}}{\text{yr}}\right)\left(\frac{\text{MT}}{2205 \#}\right) = 0.62 \ \frac{\text{metric ton}}{\text{yr}}$$

SO_2

$$\left(\frac{1067 \text{ SCF } H_2S}{10^6 \text{ SCF fuel}}\right)\left(\frac{\text{SCF } SO_2}{\text{SCF } H_2S}\right)\left(\frac{250{,}000 \text{ SCF fuel}}{\text{day}}\right)\left(\frac{64 \# \ SO_2}{379 \text{ SCF}}\right)\left(\frac{365}{220 \text{ S}}\right)$$

$$= 7.5 \ \frac{\text{MT}}{\text{yr}}$$

$$= 0.24 \text{ g/s}$$

CO Based on AP-42, CO would be

$$\left(\frac{17 \#}{10^6 \text{ SCF}}\right)\left(\frac{250{,}000 \text{ SCF}}{\text{D}}\right)\left(\frac{365 \text{ day/yr}}{2205 \#/\text{MT}}\right) = 0.7 \ \frac{\text{MT}}{\text{yr}}$$

However, this flame is at a lower temperature and is not nearly as well mixed as in any firebox with forced air injection.

Assuming only 1% of the carbon in the fuel becomes CO (rather than CO_2 or unburned HC) the CO emission would be:

One mole = 49.4 # gas

	Mole %	# carbon / mole	# carbon / mole OH gas
C_1	(6.5%)	12	0.8
C_2	(13.3%)	24	3.2
C_3	(32.8%)	36	11.8
C_4	(27.7%)	48	13.3
C_5	(9.8%)	60	5.9
C_6	(6.5%)	72	4.7
			39.7

$$\left(\frac{39.7\ \#\ C}{\text{mole gas}}\right)(1\%)\left(\frac{\text{mole}}{379\ \text{SCF}}\right)\left(\frac{28\ \#\ CO}{12\ \#\ C}\right)\left(\frac{250{,}000\ \text{SCF}}{D}\right)\left(\frac{365\ D/yr}{2205\ \#/MT}\right)$$

$$= 100\ \frac{\text{metric ton}}{\text{yr}}$$

Actual number is most likely between these.
Assume 50 metric tons/yr (1.59 g/s) as an estimate.

HC

AP-42 gives $\left(\frac{3\ \#}{10^6\ \text{SCF}}\right)\left(\frac{250{,}000\ \text{SCF}}{D}\right)\left(\frac{365\ D}{yr}\right)\left(\frac{\text{metric ton}}{2205\ \#}\right)$

$$= 0.1\ \text{metric tons/yr}$$

A better conservative estimate is to assume 2% of the fuel does not combust due to the mixing.

$$(2\%) \left(\frac{250{,}000\ \text{SCF}}{\text{d}}\right) \left(\frac{49.4\ \#}{379\ \text{SCF}}\right) \left(\frac{365\ \text{D}}{\text{yr}}\right) \left(\frac{\text{MT}}{2205\ \#}\right)$$

= 100 metric tons/yr

= 3.2 g/s

$\underline{NO_x}$

AP-42 gives $\left(\frac{230\ \#}{10^6\ \text{ft}^3}\right) \left(\frac{250{,}000\ \text{SCF}}{\text{D}}\right) \left(\frac{365\text{D}}{\text{yr}}\right) \left(\frac{\text{MT}}{2205\ \#}\right)$

= 10 MT/yr

= 0.32 g/s

The low flare temperatures will produce very low thermal NO_x formation, however, the high excess air present will contribute to higher O_2 availability.

Estimated emissions from flaring crude tower overhead gas.

SUMMARY

Pollutant	Metric tons per year	Basis
Particulates	0.6 = 0.02 g/s	AP-42
SO_2	7.5 = 0.24 g/s	1070 ppm H_2S in crude tower overhead gas. Ratio'd from estimated crude sulfur to data from U.S. refinery.
CO	50 = 1.59 g/s	0.5% of carbon in fuel is converted to CO. The AP-42 number would be only 0.7 metric tons/yr. Carbon conversion estimate is very rough.
HC	100 = 3.2 g/s	Assumes 2% of the fuel does not combust due to poor mixing
NO_x	10 = 0.32 g/s	AP-42

APPENDIX C

METEOROLOGICAL DATA PROCESSING

DATA SOURCES

Three sources of meteorological data were used to develop the annual Joint Frequency Function (JFF) and the modified short-term PREP data files for the modeling effort:

- Prudhoe Bay meteorological monitoring data,
- Barter Island National Weather Service (NWS) upper air data, and
- Prudhoe Bay acoustic sounder mixing heights for the winter night period.

Data for the period from April 1, 1979 through March 31, 1980 were processed according to the flow diagram shown in Figure C-1. The Prudhoe Bay monitoring data that were processed include 10-meter wind direction, wind speed, and temperature measurements from the Well Pad A site (Trailer 041) and 60-meter wind direction standard deviation measurements (σ_θ) from the Sohio Tower site (Site 039).

STABILITY CLASS DETERMINATION

Hourly stability class estimates were made according to the modified σ_θ method recommended in the Guideline on Air Quality Models, Proposed Revisions (EPA OAQPS Guideline Series, October 1980), with two exceptions:

- the σ_θ measurements from 60 meters were used, with a modification of the stability class limits to apply to 60 meters, since 10 meter σ_θ measurements were not available, and

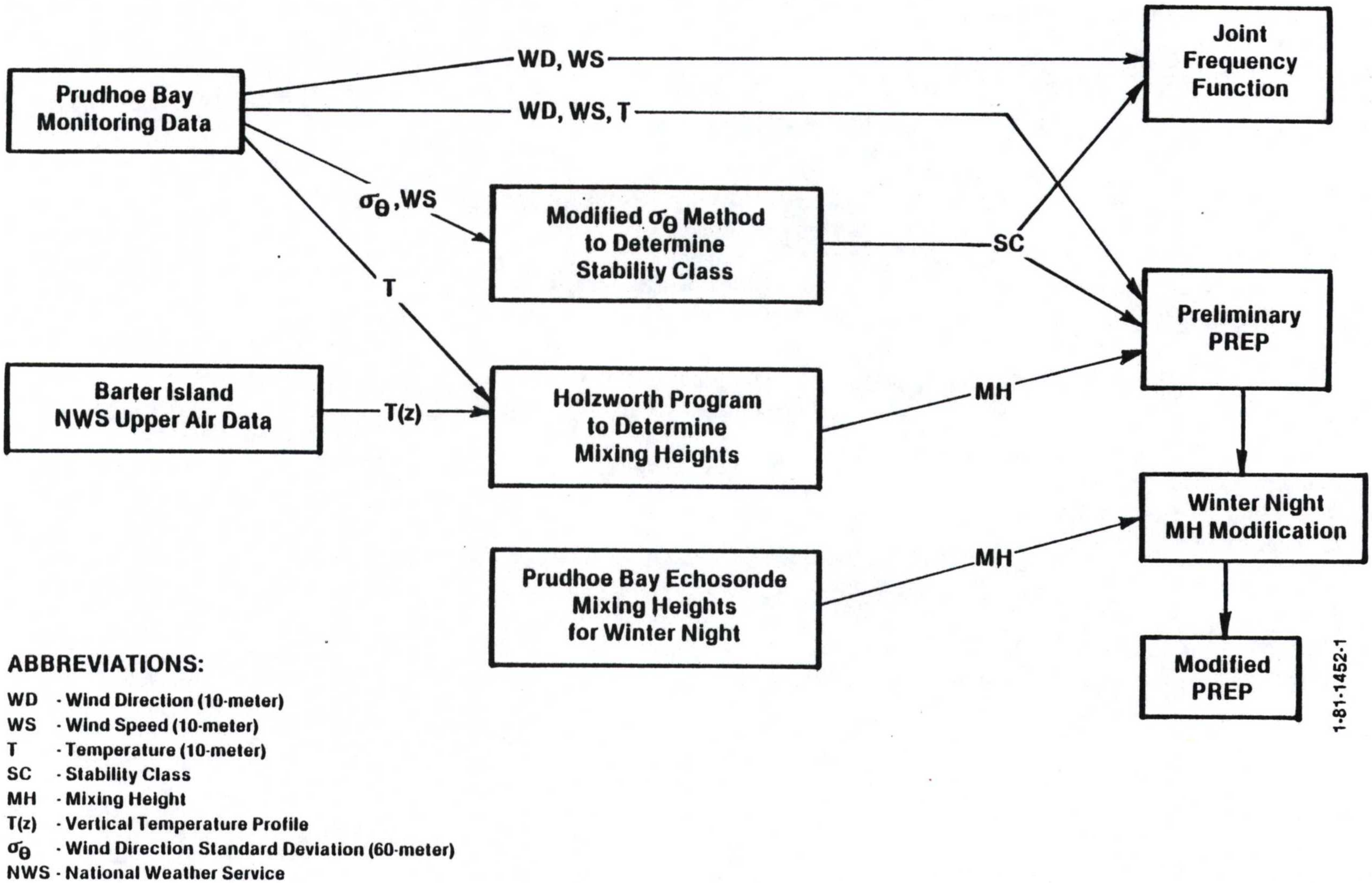

Figure C-1. Flow Diagram for Meteorological Data Processing.

- E and F stability class estimates that occurred when 10-meter wind speeds greater than 11 knots were changed to D stability.

The formula given by Sedefian and Bennett in "A Comparison of Turbulence Classification Schemes" (Atmospheric Environment, Vol. 14, pp. 741-750, 1980) was used to adjust the σ_θ stability class ranges, as follows:

$$\sigma_\theta(60\ \text{m}) = \sigma_\theta(10\ \text{m})\ (60/10)^{P_\theta}$$
$$= \sigma_\theta(10\ \text{m})\ 6^{P_\theta}$$

where P_θ = -0.06 for A stability
= -0.15 for B stability
= -0.17 for C stability
= -0.23 for D stability
= -0.38 for E stability
= -0.53 for F stability

The σ_θ ranges for 60 meters were also modified to account for the surface roughness as recommended by the modeling guidelines. A roughness parameter of Z_o = 0.27 cm was used. This roughness value was determined from 40 and 60 meter wind speed observations at the SOHIO tower, using the logarithmic profile equation. Accordingly, the multipying factor for adjusting the σ_θ ranges for surface roughness is

$$(Z_o/15\ \text{cm})^{0.2} = 0.45$$

Following this procedure, a new set of σ_θ stability class ranges was generated and used for the Prudhoe Bay applications:

Stability Class	Adjusted σ_θ Ranges for 60 Meters
A	$9.1° < \sigma_\theta$
B	$6.0° < \sigma_\theta \leq 9.1°$
C	$4.2° < \sigma_\theta \leq 6.0°$
D	$2.2° < \sigma_\theta \leq 4.1°$
E	$0.9° < \sigma_\theta \leq 2.2°$
F	$\sigma_\theta \leq 0.9°$

For nighttime conditions (one hour prior to sunset to one hour after sunrise) adjustments to the stability class estimates were made according to the new modeling guidelines, as follow:

If the nighttime σ_θ stability class was	And if the 10m wind speed, u, was m/s	mi/hr	Then the stability class was changed to
A	$u<2.9$	$u<6.4$	F
	$2.9 \leq u<3.6$	$6.4 \leq u<7.9$	E
	$3.6 \leq u$	$7.9 \leq u$	D
B	$u<2.4$	$u<5.3$	F
	$2.4 \leq u<3.0$	$5.3 \leq u<6.6$	F
	$3.0 \leq u$	$6.6 \leq u$	D
C	$u<2.4$	$u<5.3$	E
	$2.4 \leq u$	$5.3 \leq u$	D
D	wind speed not considered		D
E	wind speed not considered		E
F	wind speed not considered		F

MIXING HEIGHT DETERMINATION

The Holzworth program from the National Climatic Center was used to compute twice-daily mixing heights based on the vertical temperature profiles from Barter Island in conjunction with 10-meter temperatures monitored at Prudhoe Bay. These twice daily mixing heights were input to the PREP preprocessor program to calculate hourly mixing heights for the one-year period. PREP was not designed to handle situations in which the meteorological data is collected at a monitoring site above the Arctic Circle. Therefore, PREP was modified to handle the impact of the circumpolar sun on processing meteorological data. These modifications are identical to those discussed in the Unit Owners' Waterflood Application.

Hourly mixing heights produced by the modified PREP program were used for the entire period except for October 2, 1979 through February 2, 1980 when the maximum daily sun elevation above the horizon was less than about 10 degrees. The PREP determination of mixing heights is not applicable to the winter nighttime conditions that occur at Prudhoe Bay because it assumes that unstable conditions occur each day due to solar heating. For the winter nighttime period, mixing height measurements made by an acoustic sounder at Prudhoe Bay were used. Only mixing heights identified with a capping elevated inversion were used in this case. For times during the winter period where a capping inversion was not present, the mixing height was considered to be undefined and an arbitrary, large volume of 5,000 meters was used.

The annual mixing height for long-term modeling was determined by averaging the Holzworth determined afternoon mixing heights. An annual average value of 300 meters was calculated.

APPENDIX D
DISPERSION MODELS

ISC

The Industrial Source Complex (ISC) Gaussian dispersion model (Bowers et al, 1979) is a set of two computer programs that can be used to assess the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. The short-term version of ISC is ISCST and is used to predict short-term ambient concentrations. The long-term version of ISC is ISCLT and is used to predict annual or seasonal average ambient concentrations. The ISC model is designed for use with non-reactive pollutants. ISC is a multiple source model capable of predicting the interactive impacts of groups of sources under either rural or urban conditions and in flat or gently rolling terrain. Sources can be either point sources, volume sources, or area sources.

Briggs' plume rise formulas (Briggs, 1971, 1975) are incorporated into ISC and allow for the computation of distance-dependent and final plume rise for both buoyancy and momentum dominated plumes. In addition, ISC accounts for the effects of stack tip aerodynamic downwash and the effects of aerodynamic wakes and eddies formed by buildings and other structures on plume dispersion (Huber and Snyder, 1976) (Huber, 1977).

The ISC dispersion model is designed to calculate the effects of gravitational setting and dry deposition for plumes containing particulate matter and dry deposition for plumes containing gaseous pollutants. Alternately, the ISC model can calculate total dry deposition in lieu of ambient concentrations. A wind-profile exponent law is used to adjust the observed wind speed from the measurement height to the physical emission height for plume rise and concentration calculations. The Pasquill-Gifford curves (Turner, 1970) are used to calculate lateral (σ_y) and vertical (σ_z) plume spread.

The ISCST model uses sequential hourly inputs of ambient temperature, wind speed, wind direction, stability class, and mixing height to compute concentration or deposition values for averaging periods from 1 to 24 hours. If used with a season or year of sequential hourly meteorological data, ISCST will calculate seasonal or annual concentrations or depositions.

The ISCLT model uses a seasonal or annual statistical summary of meteorological information in the form of a joint frequency distribution of wind speed, wind direction, and stability class as meteorological input. Both seasonal and annual concentration or deposition calculations can be made with ISCLT.

PTPLU

PTPLU is a short-term Gaussian dispersion model designed to predict maximum hourly concentrations as a function of wind speed and stability for point sources located in areas of flat terrain. PTPLU is an updated version of the PTMAX Gaussian dispersion model (Turner and Busse, 1973).

A separate analysis is made for each individual stack. Input to the program consists of the source emission rate, physical stack height, and stack gas temperature. Also required are the stack gas volume flow or both the stack gas velocity and inside diameter at the top of the stack. Additional inputs to the model include the height at which the meteorological data is valid and the power law exponents used to adjust the wind speed to that expected at the physical stack height.

PTPLU determines, for each wind speed and stability class, either the final or distance-dependent plume rise using methods suggested by Briggs (Briggs, 1971, 1975). This plume rise is added to the physical stack height to determine the effective height of emissions. The effective height is used to determine both the maximum concentration and the distance to maximum concentration. The plume rise calculated by PTPLU can take into account stack tip downwash, buoyancy induced dispersion, and the effects of both buoyancy and momentum on plume rise. The Pasquill-Gifford horizontal and vertical dispersion coefficients as reported by Turner (Turner, 1970) are incorporated into the model.

REFERENCES FOR APPENDIX D

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Huber, A. H. and W. H. Snyder, Building wake effects on short stack effluents. Preprint Volume for the Third Symposium on Atmospheric Diffusion and Air Quality, American Meteorological Society, Boston, Massachusetts, 1977.

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APPENDIX E

METEOROLOGICAL DATA USED IN DISPERSION MODELING

TABLE E-1

ANN — RELATIVE FREQUENCY DISTRIBUTION — STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.002231	.005988	.002583	.000352	.000000	.000000	.011154
NNE	.001174	.005753	.001996	.000000	.000000	.000000	.008923
NE	.001292	.007514	.003053	.000235	.000000	.000000	.012093
ENE	.000704	.003640	.002583	.000352	.000117	.000000	.007397
E	.000587	.003405	.002348	.000587	.000352	.000000	.007280
ESE	.001174	.001292	.001409	.000352	.000000	.000000	.004227
SE	.000470	.002231	.001879	.000000	.000000	.000000	.004579
SSE	.000235	.001644	.000822	.000000	.000000	.000000	.002700
S	.000939	.001526	.000587	.000352	.000000	.000000	.003405
SSW	.000822	.000939	.001174	.000235	.000000	.000000	.003170
SW	.000587	.003053	.001409	.000470	.000000	.000000	.005518
WSW	.000235	.001996	.001409	.000704	.000117	.000000	.004462
W	.000704	.001761	.001057	.001174	.000117	.000000	.004814
WNW	.000704	.002583	.001174	.000352	.000000	.000000	.004814
NW	.000939	.002583	.001761	.000470	.000000	.000000	.005753
NNW	.001526	.003757	.002466	.000352	.000000	.000000	.008101
TOTAL	.014324	.049665	.027709	.005988	.000704	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF A STABILITY = .098391
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH A STABILITY = .000000

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000000	.000939	.001409	.000235	.000000	.000000	.002583
NNE	.000000	.000939	.002231	.000117	.000000	.000000	.003288
NE	.000235	.003288	.006458	.000704	.000000	.000000	.010685
ENE	.000235	.002700	.004814	.002818	.000117	.000117	.010802
E	.000235	.001879	.002583	.001526	.000117	.000470	.006810
ESE	.000117	.001292	.002935	.001292	.000000	.000117	.005753
SE	.000000	.000822	.000352	.000235	.000000	.000000	.001409
SSE	.000235	.000117	.000235	.000000	.000000	.000000	.000587
S	.000117	.000352	.000117	.000000	.000000	.000000	.000587
SSW	.000000	.000352	.001292	.000470	.000000	.000000	.002113
SW	.000117	.000704	.000939	.000235	.000117	.000000	.002113
WSW	.000235	.001057	.001174	.001057	.000235	.000117	.003875
W	.000117	.000822	.001879	.001409	.000117	.000000	.004344
WNW	.000000	.000704	.001879	.001761	.000000	.000000	.004344
NW	.000117	.000235	.000939	.000470	.000000	.000000	.001761
NNW	.000000	.000352	.000822	.000587	.000000	.000000	.001761
TOTAL	.001761	.016555	.030058	.012915	.000704	.000822	

RELATIVE FREQUENCY OF OCCURRENCE OF B STABILITY = .062815
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH B STABILITY = .000000

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ANN	RELATIVE FREQUENCY DISTRIBUTION						STATION =PRUDHOE BAY(1979-1980)
			SPEED(KTS)				
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000000	.000470	.000704	.000470	.000000	.000000	.001644
NNE	.000235	.000235	.001174	.000704	.000000	.000000	.002348
NE	.000117	.001879	.006340	.001996	.000117	.000000	.010450
ENE	.000235	.001057	.007045	.008454	.001996	.001879	.020665
E	.000117	.002231	.006223	.007162	.002700	.002113	.020547
ESE	.000117	.000822	.002466	.002231	.000235	.000000	.005871
SE	.000000	.000352	.002113	.000000	.000000	.000000	.002466
SSE	.000000	.000235	.000117	.000000	.000000	.000000	.000352
S	.000117	.000235	.000117	.000117	.000000	.000000	.000587
SSW	.000235	.000000	.000822	.000235	.000000	.000000	.001292
SW	.000000	.001292	.000822	.001526	.000000	.000000	.003640
WSW	.000000	.001057	.001526	.001996	.000235	.000235	.005049
W	.000000	.000587	.001996	.002700	.000704	.000352	.006340
WNW	.000000	.000117	.001409	.002466	.000822	.000117	.004931
NW	.000000	.000117	.000352	.000352	.000000	.000000	.000822
NNW	.000000	.000352	.000000	.000235	.000000	.000000	.000587
TOTAL	.001174	.011037	.033228	.030645	.006810	.004696	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = .087590
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = .000000

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

IDIR
IDIR
IDIR
IAAW

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
			SPEED(KTS)				
N	.000715	.001644	.003757	.000704	.000000	.000000	.006820
NNE	.001068	.001526	.003288	.003288	.000117	.000000	.009287
NE	.001445	.006692	.015616	.019608	.003522	.001057	.047940
ENE	.000961	.003875	.018786	.052366	.037807	.023600	.137393
E	.001793	.005518	.018669	.046965	.033110	.042151	.148206
ESE	.000435	.003053	.009745	.009510	.004814	.000822	.028429
SE	.000476	.001057	.002818	.001292	.000000	.000000	.005643
SSE	.000355	.000352	.001761	.001644	.000000	.000000	.004113
S	.000121	.000587	.003170	.000704	.000000	.000000	.004582
SSW	.000126	.001761	.010685	.006810	.000000	.000000	.019381
SW	.000491	.004462	.018551	.022191	.005753	.002466	.053914
WSW	.000252	.003757	.017142	.033697	.012446	.011859	.079153
W	.000374	.004696	.018199	.014324	.005636	.007280	.050509
WNW	.000249	.002935	.006575	.004579	.001057	.000587	.015982
NW	.000121	.000704	.003522	.001174	.000000	.000000	.005522
NNW	.000361	.001526	.003405	.000117	.000000	.000000	.005409
TOTAL	.009333	.044147	.155688	.218974	.104262	.089820	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = .622285
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = .000235

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

IDIR
IDIR
IDIRI
IAAM

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000359	.000470	.000704	.000000	.000000	.000000	.001533
NNE	.000601	.001174	.000939	.000000	.000000	.000000	.002715
NE	.001030	.001761	.006692	.000000	.000000	.000000	.009533
ENE	.000976	.003522	.006692	.000000	.000000	.000000	.011190
E	.000374	.002348	.005284	.000000	.000000	.000000	.008006
ESE	.000604	.001526	.001174	.000000	.000000	.000000	.003305
SE	.000121	.000352	.000000	.000000	.000000	.000000	.000473
SSE	.000006	.000704	.000000	.000000	.000000	.000000	.000710
S	.000240	.000352	.000235	.000000	.000000	.000000	.000827
SSW	.000364	.001057	.001644	.000000	.000000	.000000	.003064
SW	.000610	.002231	.006575	.000000	.000000	.000000	.009416
WSW	.000134	.001879	.006927	.000000	.000000	.000000	.008940
W	.000372	.002113	.003757	.000000	.000000	.000000	.006243
WNW	.000715	.000587	.000470	.000000	.000000	.000000	.001772
NW	.000360	.000587	.000470	.000000	.000000	.000000	.001417
NNW	.000834	.000704	.000117	.000000	.000000	.000000	.001656
TOTAL	.007749	.021369	.041681	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF E STABILITY = .070800
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH E STABILITY = .000235

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

SPEED(KTS)

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000597	.001292	.000000	.000000	.000000	.000000	.001879
NNE	.000597	.000939	.000000	.000000	.000000	.000000	.001526
NE	.000597	.001292	.000117	.000000	.000000	.000000	.001996
ENE	.000704	.001292	.000000	.000000	.000000	.000000	.001996
E	.000822	.003405	.000117	.000000	.000000	.000000	.004344
ESE	.001761	.003757	.000000	.000000	.000000	.000000	.005518
SE	.001761	.002348	.000000	.000000	.000000	.000000	.004109
SSE	.001409	.001292	.000000	.000000	.000000	.000000	.002700
S	.001526	.002348	.000000	.000000	.000000	.000000	.003875
SSW	.001526	.002231	.000000	.000000	.000000	.000000	.003757
SW	.001879	.005284	.000117	.000000	.000000	.000000	.007280
WSW	.002231	.002700	.000000	.000000	.000000	.000000	.004931
W	.002231	.002231	.000000	.000000	.000000	.000000	.004462
WNW	.001526	.002113	.000000	.000000	.000000	.000000	.003640
NW	.001057	.002348	.000000	.000000	.000000	.000000	.003405
NNW	.000822	.001879	.000000	.000000	.000000	.000000	.002700
TOTAL	.021017	.036750	.000352	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF F STABILITY = .058119
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH F STABILITY = .000000

TABLE E-2

WORST-CASE 3-HOUR METEOROLOGICAL CONDITIONS

FOR SO_2 (DAY 47, HOURS 01-03)

HOUR	WIND DIRECTION (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP (DEG. K)	STABILITY CATEGORY
1	355	2.3	Infinite*	261	F
2	349	1.6	Infinite	260	F
3	352	1.5	Infinite	259	F

*ISCST in the rural mode ignores the interpolated mixing heights for E and F stability class and effectively sets the mixing height equal to infinity.

TABLE E-3

WORST-CASE 24-HOUR METEOROLOGICAL CONDITIONS FOR SO_2 (DAY 274)

HOUR	WIND DIRECTION (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP (DEG. K)	STABILITY CATEGORY
1	91.0	10.10	512.0	272.0	D
2	94.0	10.30	512.0	272.0	D
3	92.0	10.80	512.0	272.0	D
4	92.0	11.00	512.0	272.0	D
5	90.0	11.10	512.0	272.0	D
6	91.0	10.90	512.0	272.0	D
7	87.0	11.40	50.0	272.0	D
8	88.0	10.90	116.0	272.0	D
9	90.0	11.40	182.0	272.0	D
10	89.0	12.10	248.0	272.0	D
11	86.0	11.40	314.0	272.0	D
12	87.0	12.10	380.0	272.0	D
13	88.0	12.80	446.0	272.0	D
14	86.0	13.50	512.0	272.0	D
15	85.0	14.10	512.0	272.0	D
16	84.0	14.80	512.0	272.0	D
17	83.0	13.90	512.0	272.0	D
18	83.0	13.70	512.0	272.0	D
19	84.0	14.10	512.0	272.0	D
20	84.0	14.50	512.0	272.0	D
21	83.0	14.60	512.0	272.0	D
22	84.0	15.00	512.0	272.0	D
23	85.0	15.80	512.0	272.0	D
24	82.0	15.10	512.0	271.0	D

TABLE E-4

WORST-CASE 24-HOUR METEOROLOGICAL CONDITIONS FOR TSP (DAY 272)

HOUR	WIND DIRECTION (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP (DEG. K)	STABILITY CATEGORY
1	89	12.2	512	273	D
2	87	12.1	512	273	D
3	90	12.3	512	273	D
4	91	12.2	512	273	D
5	91	11.7	512	273	D
6	92	12.0	512	273	D
7	92	11.6	512	273	D
8	93	11.4	512	272	D
9	94	11.4	512	273	D
10	96	11.1	512	273	D
11	99	9.7	512	273	D
12	97	9.0	512	273	D
13	98	9.3	512	273	D
14	93	8.4	512	273	D
15	92	8.9	512	273	D
16	93	7.8	512	273	D
17	94	8.3	512	273	D
18	94	8.1	512	273	D
19	92	8.4	512	273	D
20	93	8.7	512	273	D
21	91	8.9	512	273	D
22	96	9.7	512	273	D
23	98	9.4	512	273	D
24	97	8.9	512	273	D

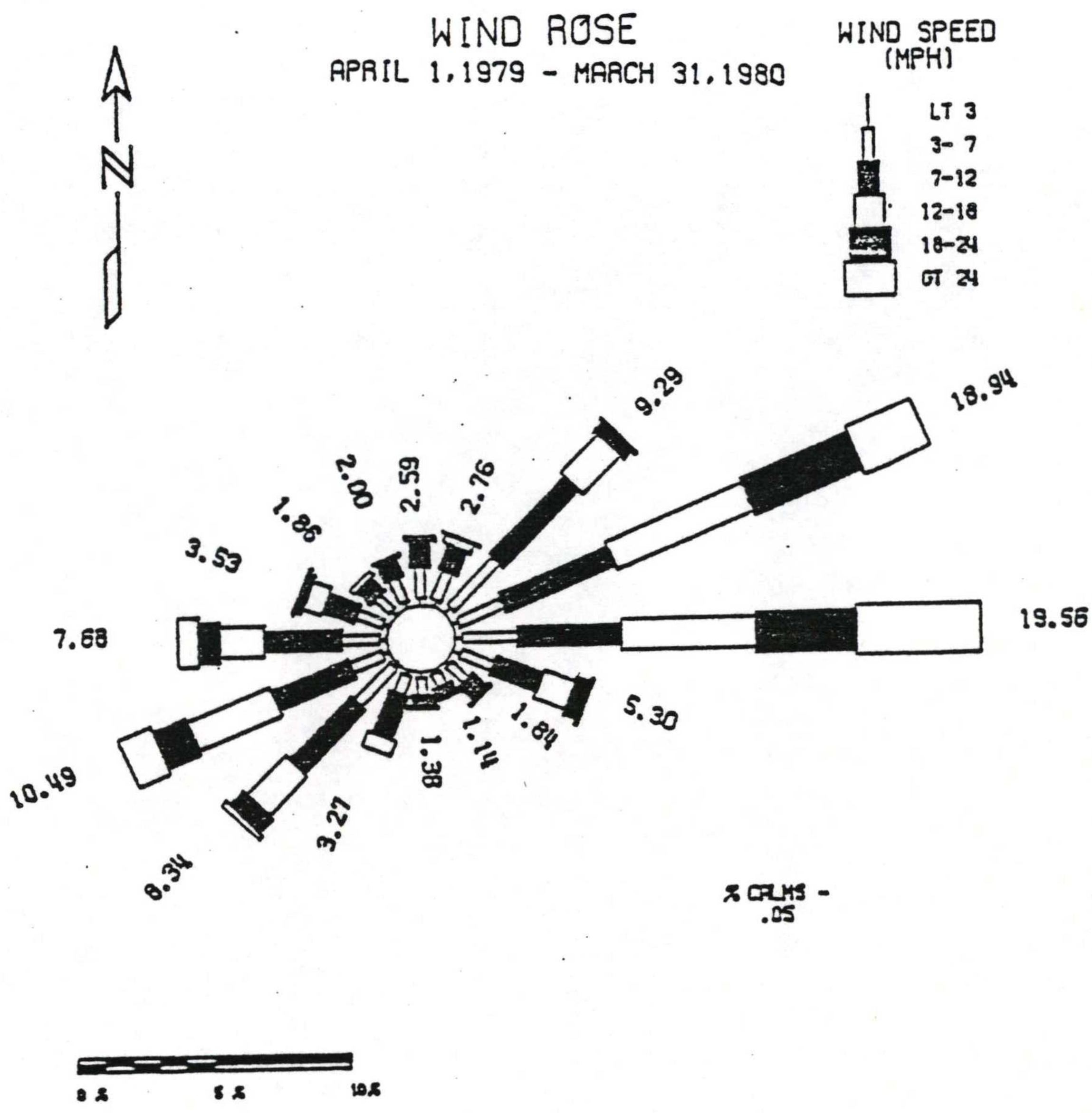
APPENDIX F
REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

Wind directions and wind speeds used in modeling were those measured at Site 1. A wind rose (joint frequency diagram) for these data is presented in Figure F-1. For comparison purposes, wind roses for Barter Island (1958-1964), the Deadhorse Airport (1976), and Barter Island (1968-1977), are presented in Figures F-2 and F-3. The similarity of wind patterns indicated for these geographically separated locations and different time periods strongly suggests that the Prudhoe Bay Site data are representative of regional climatic conditions.

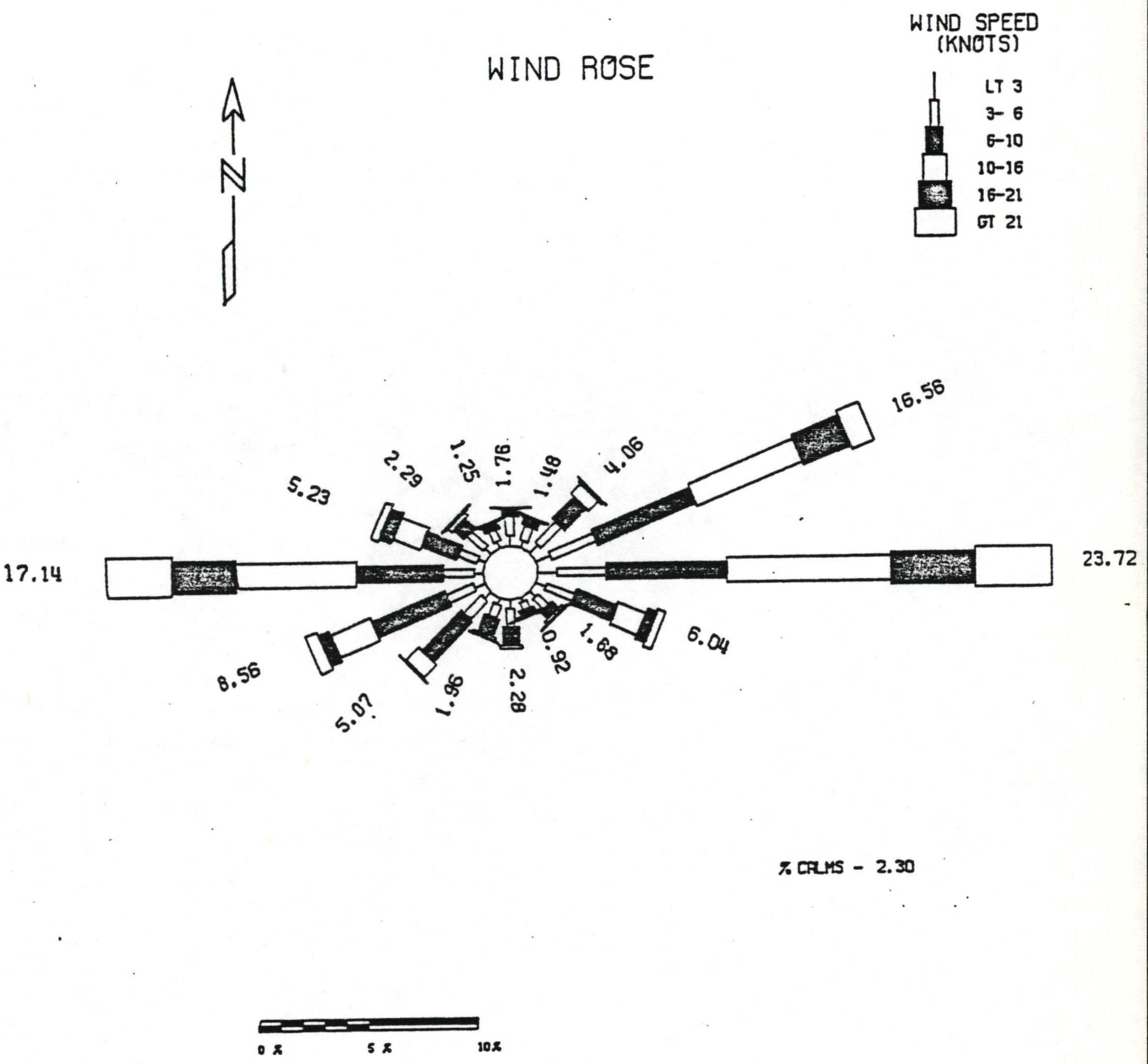
Stability class distributions for the Prudhoe Bay Monitoring Network, derived as described in Appendix C, are compared with those for Barter Island (1968-1977), which are derived by the Pasquill-Turner method, in Table F-1. When considering the differences in the bases for the stability classifications, it is concluded that the stability data from the Prudhoe Bay Network are reasonable approximations of regional conditions.

Precipitation and temperature data comparisons also indicate that the data measured at the Prudhoe Bay Monitoring Network, and used in the modeling analyses, are representative of the Kuparuk area. Precipitation data recorded during the April, 1979 to March, 1980 period at Point Barrow (3.19 inches) and Barter Island (7.20 inches) indicate a trend of increasing precipitation from west to east along the north coast of Alaska. The data for Prudhoe Bay (Site 2) for this time period (5.34 inches) is in close agreement with this trend. Temperature data recorded at the three 10-meter temperature sensors in the Prudhoe Bay Monitoring Network averaged 12.4°F. The mean annual temperature at Prudhoe Bay Airport during 1971-1973 was 7.9°F. The mean temperature at Point Barrow during the April 1979 to March 1980 period was 3.1°F higher than the climatological normal temperature established from 1941-1979; at Barter Island during the same period, the departure from the 1947-1970 climatological normal temperature was 3.3°F. This may be indicative of regional climatological change. When this difference from long-term mean temperature is considered in conjunction with the difference between 1.8-meter and 10-meter temperatures at Site 2 during the period of simultaneous measurements (more than 1°F), the Prudhoe Bay Monitoring Network data appear to be in close agreement with that expected at the Prudhoe Bay Airport.



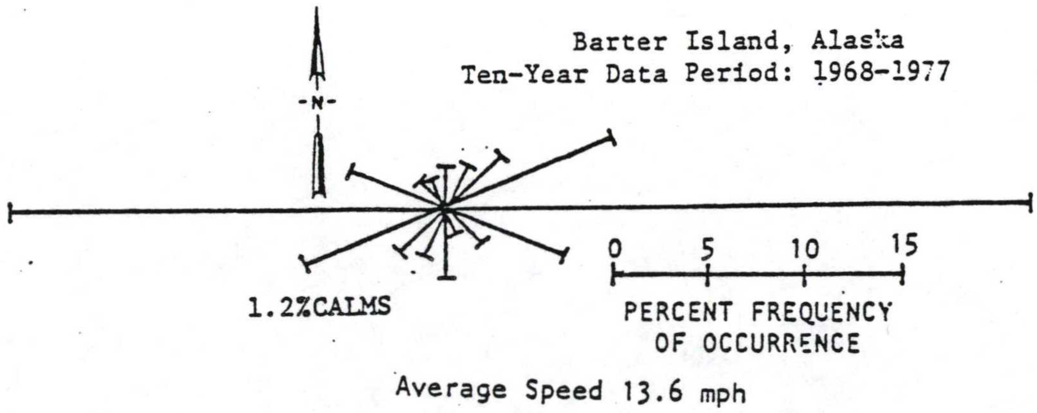
PRUDHOE BAY - WELL PAD A

Figure F-1



BARTER ISLAND, ALASKA - ANN - 1958-1964

Figure F-2



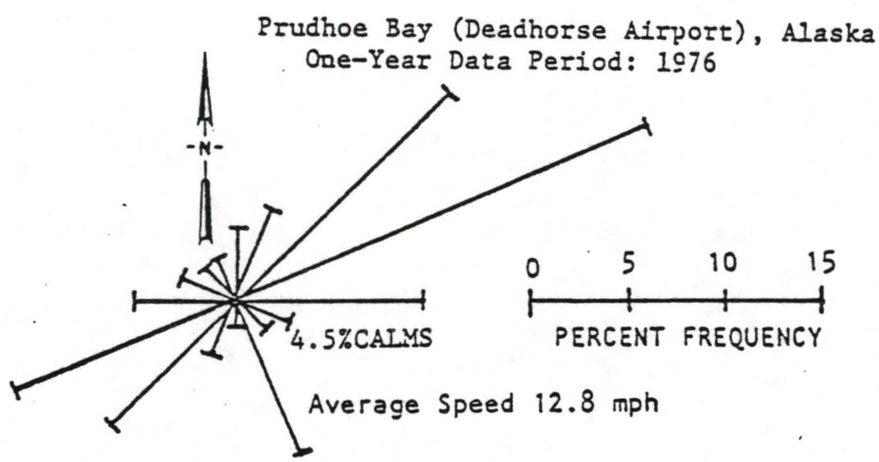


Figure F-3. Annual Wind Roses

TABLE F-1. ANNUAL FREQUENCY DISTRIBUTIONS OF PASQUILL STABILITY CLASSES WITH AVERAGE WIND SPEED BY STABILITY CLASS

		Barter Island (1968-1977)		Prudhoe Bay (1979-1980)	
Stability Class	Definition	Annual Frequency (percent)	Average Wind Speed (mph)	Annual Frequency (percent)	Average Wind Speed (mph)
A	Extremely Unstable	0.00	N/A	9.84	6.1
B	Unstable	0.86	4.7	6.28	8.4
C	Slightly Unstable	4.54	6.3	8.76	11.3
D	Neutral	79.54	13.4	62.23	14.1
E	Slightly Stable	9.36	7.9	7.08	6.7
F	Stable to Extremely Stable	5.70	3.6	5.81	3.8

ADDENDUM

Page 17, Table 3-2

CPF COT flare, stack characteristics, temperature should be changed to 1,000° K.